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THE FEEDING VALUE OF CANE MOLASSES [1]

O. A. Palad, L. L. Clamohoy and M. V. Diaz

Cane molasses partially or fully replacing ground yellow corn in concentrate mixtures of dairy animals or added as a supplement to rice straw for summer feeding of beef cattle, produces comparable results with ground yellow corn on equal or identical digestible protein (D.P) or total digestible nutrients (T.D.N.) basis.

In many countries, especially in the United States, cane molasses is extensively used as feed for livestock. In the Philippines, however, the use of molasses in the ration has been confined largely to horses.

Underfeeding of cattle during the dry season is one of the country's major livestock problems. Cane molasses used in proper combination with other feeds offers a good feed supplement for livestock on pasture.

Only few experiments on its value as feed have been conducted on swine and cattle. These tests, although limited in scope and made on few animals, showed that molasses can be a favorable substitute for corn or rice bran. Hence, these experiments were conducted in the Department of Animal Husbandry of the U.P. College of Agriculture and Central Experiment Station from March 1, 1955, to September 30, 1956.

Cross (1925) reported that molasses permits a daily economy of 28 to 40 per cent on the ordinary cost of rations and improves the health of animals. Henry and Morrison (1916) stated that molasses is especially useful in getting animals to consume roughage which would otherwise be unpalatable. Skinner and Kine, as cited by Henry and Morrison (1916), observed that steers fed 1.25 kg. of molasses, 4.95 kg. of shelled corn and 1.5 kg. of cottonseed meal gained 0.15 kg. more per head daily than cattle fed with 6.18 kg. of shelled corn and 1.5 kg. of cottonseed meal alone. Lindsey, as cited by Henry and Morrison (1916) stated that 1.3 to 1.7 kg. of molasses per head can be fed advantageously to fattening steers. Brunwich (1924) stated that the large amount of soluble salts of potash

[1] Central Experiment Station Contribution No. 869. Research Project No. 793.

in molasses act adversely on the digestion and may cause scours unless fed in moderate quantities. Faye and Fredericksen (1897) observed that animals fed in a grain ration without molasses required less feed per pound of gain and that the gains in weight were more economical than those of animals fed with a ration combined with molasses. The meat of the molasses-fed animals, however, was also found to be excellent. Roces, Jr. (1935) claimed that fattening cattle which are pastured in the daytime, housed at night and fed with supplements of molasses, rice straw and copra meal gained more weight than when they grazed on the pasture for the entire 24 hours. Alcasid (1927) found in his experiment on certain fattening feeds for hogs that molasses-fed pigs gave a higher rate of gain than corn-fed pigs and that molasses-fed pigs with starch as part of the ration gave the highest percentage of dressed weight. Gochangco (1931) reported that one part of molasses was equal to one part of corn in feeding value and that molasses could be substituted partly or wholly for corn, especially when corn is scarce or its price is high.

Investigations conducted by Bohman at the Cornell Experiment Station, from 1950 to 1952, showed that molasses fed as a concentrate with late-cut hay to growing dairy heifers did not produce good gains compared to corn meal fed to heifers in similar ration. Under those conditions, molasses was found to be an inadequate source of carbohydrates for the utilization of urea by bacteria. The inclusion of early-cut legume hay greatly improved the utilization of molasses from these rations. This may have been due to the increased amount of protein or other nutritive factors supplied in the hay.

I. FOR ARTIFICIALLY RAISED NURSING MURRAH CALVES[2]

MATERIALS AND METHODS

Ten 3-month old Murrah calves were divided into two groups according to their average body weights taken on three consecutive days at the start of the experiment.

The groups were housed side by side in concrete-floored barn sheds provided with equal sizes of paddocks. A long wooden feed trough partitioned in the center was placed across the fence dividing the two groups. It was big enough to prevent feed spillage and crowding of the animals during feeding. An improvised soilage rack

[2] Mr. Francisco Bravo, Jr., helped conduct the experiment.

made of bamboo poles, ipil-ipil wood and rattan was constructed on both ends of each paddock. Abundant water supplied in metal containers was provided for each group.

The following rations were used:

INGREDIENTS	GROUP I (Experimental)	GROUP II (Control)
	per cent	*per cent*
Ground Yellow Corn	18	28
Sugar cane Molasses	10	
Fine Rice Bran, Ordinary	25	25
Ground Copra Meal	25	25
Skim milk Powder	20	20
Ground Shells	1	1
Table Salt	1	1
Total	100	100

Concentrates were given every morning and soilage, every morning and afternoon. Records of the initial and final weights and body measurements for three consecutive days and of the grains and soilage consumption were taken.

RESULTS AND DISCUSSION

Body weight and measurements. The differences in gains in weight and body measurements of the calves in both groups were statistically insignificant. This finding showed that molasses replacing 10 parts of corn in the concentrate mixture gives comparable results for nursing calves raised artificially (table 1).

Feed consumption. The concentrate consumption in each group was the same. The roughage consumption of animals in the molasses-fed group was slightly greater, although the difference was not statistically significant.

II. FOR GROWING DAIRY HEIFERS AND CARABAOS

MATERIALS AND METHODS

Two Red Sindhi and four Red Sindhi-Holstein heifers ranging in weight from 119.7 to 212.3 kg. were used in set I. Eight grade and pure Murrah carabaos ranging in weight from 154.3 to 266.7 kg. were used in set 2. Set 2 was repeated using the same animals but in different groups.

TABLE 1.—*Effect of feeding cane molasses on the live weight and body measurements of nursing Murrah calves*

	GROUP I (Experimental)	GROUP II (Control)
No. of calves per group	4	4
No. of days on trial	102	102
Av. initial weight, kg.	72.2	65.5
Av. final weight, kg.	135.6	128.5
Av. total gain per head, kg	15.0	15.8
Av. daily gain, kg.	.15	.15
Av. initial height, cm.	34.0	33.0
Av. final height, cm.	39.8	40.4
Av. total gain per head, cm.	5.8	7.4
Av. daily gain, cm.	.05	.07
Av. initial length, cm.	32.9	31.2
Av. final length, cm.	38.3	36.8
Av. total gain per head, cm.	5.4	5.6
Av. daily gain, cm.	.05	.05
Av. initial heart girth, cm.	38.3	37.5
Av. final heart girth, cm.	46.1	48.7
Av. total gain per head, cm.	7.8	11.2
Av. daily gain, cm.	.07	.11
Total feed consumption		
Concentrates	960.0	960.0
Roughage (soilage)	1,282.4	1,272.8
Total feed consumed per animal		
Concentrates	240.0	240.0
Roughage (soilage)	320.6	318.2
Feed per 100 kg. gain in weight		
Concentrates	160.0	150.0
Roughage (soilage)	210.0	200.0

Two rectangular barns were used for each class of dairy livestock. The respective groups of each part were housed side by side in one-half of the barn which was partitioned lengthwise. Runs were provided for each group by extending hogwire on the eastern ends of the partition of the barns outside, thus making enclosures on both sides.

Wooden feed troughs were built on each side along the entire length of the walls and a roughage rack was constructed above each trough. Boxes for minerals and salt were placed on both ends of the feed troughs. Metal-sink water containers were provided in each lot. An American pitless scale calibrated to 5000 kg. for weigh-

ing the animals and a Hanson spring balance calibrated to 20 kg. for weighing feeds were used.

In set 1 six dairy heifers, three animals to a group, were used.

The concentrate mixture given to the animals consisted of the following ingredients, all parts by weight:

INGREDIENTS	GROUP I (Experimental)	D.P. (kg.)	T.D.N. (kg.)	GROUP II (Control)	D.P. (kg.)	T.D.N. (kg.)
Cane Molasses	1.1	0.004	0.590	—	—	—
Ground Yellow Corn	—	—	—	0.7	0.054	0.589
Fine Rice Bran	0.8	0.060	0.487	0.8	0.060	0.487
Copra Meal	0.7	0.102	0.550	0.7	0.102	0.550
Fish Meal	0.42	0.165	0.244	0.3	0.118	0.175
Total	3.02	0.331	1.871	2.5	0.334	1.801

The total amount of feed needed for each animal based on the average initial weight was 3.02 kg. for group I and 2.5 kg. for group II. The corresponding amounts of digestible protein (D.P.), and total digestible nutrients (T.D.N.), in the feeds were based on Morrison's Feeding Standard.

In set II the eight growing dairy carabaos were divided at random into two groups of equal number of females and males. The concentrate mixture given to the animals consisted of the following ingredients, all parts by weight:

INGREDIENTS	GROUP I (Experimental)	D.P. (kg.)	T.D.N. (kg.)	GROUP II (Control)	D.P. (kg.)	T.D.N. (kg.)
Cane Molasses	2.3	0.009	1.23	—	—	—
Ground Yellow Corn	—	—	—	1.5	0.115	1.26
Fine Rice Bran	1.0	0.075	0.61	1.0	0.075	0.61
Copra Meal	0.5	0.072	0.39	0.5	0.072	0.39
Fish Meal	0.4	0.192	0.25	0.2	0.097	0.13
Total	4.2	0.351	2.48	3.2	0.359	2.392

As in set I the total amount of feed needed for each animal based on the average initial weight was 4.2 kg. for group I and 3.2 kg. for group II. The corresponding amounts of D.P. and T.D.N. in the feeds were also based on Morrison's Feeding Standard.

In the repetition of set 2 the same growing dairy carabaos were used and divided at random into two groups of equal number of females and males. The concentrate mixture given to the animals consisted of the following ingredients, all parts by weight:

INGREDIENTS	GROUP I (Experimental)	D.P. (kg.)	T.D.N. (kg.)	GROUP II (Control)	D.P. (kg.)	T.D.N. (kg.)
Cane Molasses	2.3	0.009	1.230	—	—	—
Ground Yellow Corn	—	—	—	1.5	0.115	1.263
Fine Rice Bran	1.0	0.075	0.609	1.0	0.075	0.609
Copra Meal	0.5	0.072	0.392	0.5	0.072	0.392
Fish Meal	0.6	0.292	0.384	0.4	0.195	0.256
Total	4.4	0.448	2.615	3.4	0.457	2.520

The total amount of feed needed for each animal based on the average initial weight was 4.4 kg. for group I and 3.4 kg. for group II. The corresponding amounts of D.P. and T.D.N. in the feeds were again based on Morrison's Feeding Standard.

Ingredients in the rations appear in different proportions on account of the difference in T.D.N. of corn meal and molasses. The rations were computed for differences in amounts of corn and molasses. The dry constituents of each ration, enough to last throughout the entire experimental period, were mixed before the experiment started. The animals were fed with the mixture once a day in the built-in feed rack. Molasses was thoroughly mixed over each experimental feed mixture.

The amount of feed needed for each animal was based on the average initial weight.

A preliminary feeding period of two weeks using the control ration was made to determine the average consumption of the animals for the concentrate. Then the amounts given were established to meet the total digestible nutrients and protein requirements for the average of the animals that were used in the experiment. It was assumed that the larger animals would consume enough concentrates to meet their nutritive requirements. The same mixture was given to both groups in each experiment, with only cane molasses in Group I replacing the total digestible nutrients furnished by the ground corn in the control ration. Sufficient fish meal was added to this experimental ration to equalize the digestible protein supplied by the control ration. The addition of roughage offset possible protein deficiency in the concentrate mixture of either group.

Besides the concentrate, roughage was given every afternoon. The animals in set 1 of the experiment received mixed grass soilage during the first five weeks, Alabang X silage for the next six weeks and corn silage during the last five weeks of the experimental

feeding period. Rice straw was given to each group as roughage supplement in the first experiment in set 2.

Excessively large quantities of feed were given to the animals during the first few days of the experiment to provide plenty of weigh-back for determining the amounts consumed. The quantity of roughage fed was based on the amount consumed by the group with the lowest intake. There was no adjustment made in the amount of concentrates given during the entire experiment. The amounts of roughage, however, were gradually increased as the animals gained in weight and became older.

A mixture of salt and minerals (ground oyster shells) was provided *ad libitum.*

The animals were weighed daily for three days and the average of these weights was considered their initial weight. From the fourth day, the animals were weighed at 28-day intervals. At the end of the experiment, the average of the daily weights taken on the last three days was considered the final weight.

Weigh-backs of the roughages and concentrates were taken daily and subtracted from the original amount given for the daily consumption of each group.

RESULTS AND DISCUSSION

Body weight. The molasses-fed group of growing dairy heifers made 0.65 kg. average daily gain in weight, and the corn-fed group made 0.53 kg. On the average, the molasses-fed group made 0.12 kg. more gain in weight than the control group.

The average daily gain in weight of the molasses-fed group was 0.62 kg. and that of the corn-fed group, 0.44 kg. On the average the molasses-fed group made 0.18 kg. more gain in weight daily than the control group.

On the replication using the same animals the molasses-fed group made 0.63 kg. average daily gain in weight, 0.09 kg. more than that (0.54 kg.) of the corn-fed group.

Although the analysis of variance showed that the differences in gain between the groups in either set I or II were not statistically significant, cane molasses may be considered a good substitute for ground corn in the ration for both growing carabaos and dairy heifers. These results agree with the findings of Burns, as cited by Henry and Morrison, (1916) and Gerlaugh (1932), that

molasses, as replacement for corn results in more gain in weight of steers and calves.

Feed consumption and feed cost. The plan of the experiment was to add approximately identical amounts of T.D.N. in the rations of both experimental and control groups. Both groups had practically equal daily consumption of roughage and concentrates, and yet the molasses-fed groups had slightly bigger gains. In spite of the lower roughage intake of the molasses-fed group, the amount of feed it required to produce a kilogram gain was lower than that of the corn-fed group.

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* * *

False facts are highly injurious to the progress of science for they often endure long; but false views if supported by some evidence do little harm, for everyone takes a salutary pleasure in proving their falseness.

—Darwin

* * *

Science needs the penetrating criticism of philosophy to preserve its equilibrium and it needs the wings of literature and art to bear its conclusions to their destination.

—Albert Davis

PLANT CHARACTERS, FIBER, AND CYTOLOGY OF MUSA BALBISIANA x MUSA TEXTILIS F_1 HYBRIDS [1]

F. A. Bernardo [2]

WITH SIX PLATES

Most of the first generation hybrids between pacol (*Musa balbisiana* Colla) and abacá (*Musa textilis* Née) exhibited plant characters intermediate to those of pacol and abacá and strikingly similar to those of canton, a putative hybrid of the two species. Close affinity between the F_1 hybrids and canton is also strongly suggested by their similarities in the presence of characteristic streaks on the bracts, abnormalities in the floral structure, and high degree of sterility.

Extreme variabilities, notably height of plant, size of stalk, color of leaf sheath, compactness of fruits, shape of male bud and pendulousness of the inflorescence were observed among the hybrids. Some of the abnormalities of the floral structures were reduplication of the corolla and non-functional pistil and reduction in the number of stamens.

Coloration of the pseudostem and midrib in abacá appeared to be dominant over the absence of coloration in pacol; the waxy bloom and coloration of the compound tepal of pacol showed dominance over the absence of the two characters in abacá.

The hybrids were highly variable in fiber quality and quantity. Majority of the clones studied had very low percentage of fiber extraction. One ranked with abacá in amount of extractable fiber. The best among the hybrids in tensile strength equaled only the best among the different clones of pacol and canton. On the average, abacá fiber was more than thrice stronger than that of pacol, whereas the fibers of the hybrids and canton were 1-1/6 times stronger than pacol. The fibers of abacá were the coarsest, those of pacol the finest, and those of the hybrids and canton, intermediate. Abacá fiber had the highest percentage of stretch, pacol the lowest, and pacol-abacá and canton, intermediate to the two parental species. With tensile strength, coarseness and percentage of breaking length as criteria of selection, the F_1 hybrids were considered unsatisfactory.

All the hybrids that had so far flowered proved to be completely female sterile. The use of insufficient pollen grains occasionally produced by the hybrids set viable seeds on abacá variety Expt. Sta. 3.

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[1] Central Experiment Station Contribution No. 870. Thesis submitted to the Graduate School, U.P., 1957, for the M.Sc. degree.

[2] The writer is greatly indebted to Dr. D. L. Umali who produced the materials for study, suggested the problem and gave valuable suggestions during the progress of the experiment; to Dr. J. M. Capinpin for advice on the study on plant characters and cytology; and to Dr. L. Clemente and Miss Mary Caluya for critical reading of the manuscript.

Two clones of the first generation hybrid showed a complement of twenty-one chromosomes.

The two types of male sterility observed were complete sterility and high sterility, i.e., occasional production of scanty pollen grains. The first was found to be due to the disintegration of the cytoplasm at the prophase stage of meiosis, which is attributable to genetic factors, and the second was found to be due to non-homology of the chromosomes in the two genomes, leading to several abnormalities in the meiotic division and subsequent formation of polyspores. A few irregularly shaped quartets containing no micronuclei were produced, arising probably from a more stable meiosis.

A study on karyotype is suggested to determine the definite relationship between the F_1 hybrids and canton, the supposedly derived hybrid of *Musa balbisiana* and *Musa textilis*.

Abacá production in the Philippines has been seriously set back due to World War II and the subsequent occurrence of mosaic (*Marmor cucumeris* Holmes) in Mindanao plantations. The average abacá production in the country dropped from 173,400 tons in 1934-1939 (Cruz, 1947) to 114,600 tons in 1952 (Cruz, 1953a). This decrease in production was attributed to mosaic disease. Conclusive evidence showed that the disease not only affects fiber yield per unit area but also the fiber quality (Cruz, 1954). Agati (1953) and Reinking (1949) noted that mosaic infection in most plantations in Davao and Cotabato, involving over 50,000 hectares, ranged from one to 40 per cent in some cases and from 60 to 100 per cent in others.

A Mosaic Control Campaign, started in 1949 by the Bureau of Plant Industry, consisted mainly of control measures by elimination of diseased clones and insect vectors and suggestions of proper cultural practices. The disease has not been fully controlled because of the failure of the growers to wage the control campaign and the tremendous, uncontrolled expansion of new areas planted to abacá (Kent, 1954). Apparently, the best method of control would be the use of mosaic-resistant strains which could be achieved only through breeding, as there is no abacá variety known to be resistant to mosaic. Growing of resistant strains is more permanent and eventually less expensive to the industry.

The current abacá breeding program in the U.P. College of Agriculture, Guinobatan Abacá Experiment Station, Davao Abacá Experiment Station and Economic Garden at Los Baños, Laguna is designed primarily to produce abacá hybrids resistant to mosaic. It appears that pacol (*Musa balbisiana* Colla), "agotay" (*M. acuminata* Colla) and canton and "minay", both putative hybrids of

pacol and abacá, are possible sources of resistance to abacá mosaic and bunchy-top. The first two *Musa* species are completely resistant to abacá mosaic while the other two possess only a high degree of resistance (Bernardo and Umali, 1956). First generation hybrids of pacol and abacá were produced at the College of Agriculture, Davao Abacá Experiment Station and Economic Garden and tests for disease resistance showed that the F_1 progenies produced at the College of Agriculture are highly resistant to abacá mosaic and bunchy-top (Umali and Bernardo, 1955) although very susceptible to vascular wilt disease (Umali *et al.*, 1956).

The present work deals with the analytical study of the first generation hybrids of pacol (*M. balbisiana*) and abacá (*M. textilis*) produced in the Division of Plant Breeding, U.P. College of Agriculture, Los Baños, Laguna.

This study was undertaken from May, 1955 to April, 1957, in the laboratories of the Divisions of Plant Breeding and Industrial Crops.

I. PLANT CHARACTERS

MATERIALS AND METHODS

Forty-six *Musa balbisiana* x *M. textilis* F_1 hybrid selections from more than 1,200 seedlings produced in 1953 by using pacol (*M. balbisiana*) as seed parent and abacá (*M. textilis*) as pollen parent, were planted in the Plant Breeding nursery in February, 1955. Since the pollen parents were abacá, only seedlings with the characteristics of abacá, like coloration of pseudostems and narrow leaves, were selected to make sure that the resultant seedlings were combinations of germplasm for the parental types utilized for fertilization. The abacá clones used were Maguindanao x Kinalabaw, Putian x Kinalabaw, Putian x Jolo and Sugmad. Because a test for resistance was conducted under greenhouse conditions transplanting was delayed. This rigid selection was resorted to because a vast area would have to be occupied if all the seedlings were transplanted.

One shortcoming in the plant materials studied was that the varietal designation of the abacá parent of each hybrid plant was not definitely known, as a result of technical inadvertence in the handling of seedlings. However, from the practical standpoint of producing hybrids with disease resistance and good quality fibers, this shortcoming is negligible considering that abacá is remarkably heterozygous. Abacá plants grown from seeds exhibit a high degree

of variability, in their vigor, number and length of roots, height, stalk diameter, leaf sheath and petiole color, leaf sizes, stooling capacity and fiber content (Mendiola, 1923; Baliguas, 1955; Ricahuerta, 1952).

Moreover, it is contemplated that the backcross method of breeding for disease resistance is to be employed, in which different leading commercial abacá varieties of the Bicol, Samar-Leyte and Davao regions will be used as recurrent parents.

Twelve pacol-abacá hybrid clones (clone nos. 4, 5, 6, 8, 9, 22, 23, 24, 25, 26, 28 and 36) including four pacol clones growing wild in College and four clones of canton in the nursery of the Division of Industrial Crops were studied.

Plant characters were studied and measurements taken when the plants were at the flowering stage. The maturity of the plants was rather delayed and not uniform. Many clones had not yet flowered up to the time this study was written. Seed-grown abacá and pacol plants mature within 2½ years. The delay in flowering may be due to the much delayed transplanting of the hybrid seedlings.

RESULTS AND DISCUSSION

The plant characters of the hybrids in relation to the parental plants and the putative natural hybrid canton were studied. The description of abacá (Pl. I, fig. 1), *Musa textilis* Née, by Cheesman (1949) and the description of pacol (Pl. I, fig. 3), *Musa balbisiana* Colla also by Cheesman (1948) were compared with the plant characters of the hybrids. Plant characters of canton, a putative hybrid of *M. balbisiana* and *M. textilis* as described by Gorrez (1955) was also compared with that of the hybrids.

The present study showed great variability in most of the important plant characters of the hybrids. At flowering time the number of stools of each clone differed considerably. Most clones were poor stoolers, having only 3 or 4 stools. Two clones with 11 and 8 daughter stalks may be considered fair stoolers. Seven abacá varieties studied by Baliguas (1955) gave 17 stools on the average.

The height of the plants measured from the ground to the end of the solid stalk ranged from 2.4 to 6 meters with an average of 3.63 meters. The stem diameter at 50 and 100 cm. from the base, with averages of 19.10 and 16.46 cm. respectively, showed much variability. The leaf sheath color ranged from green to dark purple

Fig. 1.—A clone of abacá, *Musa textilis* Née var. Expt. Sta. No. 3.
Fig. 2.—A clone of pacol-abacá F_1 hybrid.
Fig. 3.—A clone of pacol, *M. balbisiana* Colla.

at the basal part of the stalk. The sheaths were either glaucous, slightly glaucous or not glaucous.

The averages of the measurements of three mature leaves taken from each stalk also showed great variability in length and width. The calculations for the ratio of the width at 20 cm. from the tip to the maximum width of the leaf ranged from 34.28 per cent for the most tapering leaf to 69.35 per cent for the least tapering. The black lining at the nether surface of the right blade, a characteristic marker that is conspicuous in abacá and almost invisible or absent in pacol, was either present or absent in some of the clones. Most midribs of different clones were pinkish or purplish, a characteristic inherited from the abacá parents used, most probably from Sugmad.

The inflorescence varied from almost horizontal to very pendulous. All were glabrous.

The male bud, described in advanced blooming, varied from globose to very oblong which are uncommon in abacá, pacol and canton. The shape of all others, however, resembled that of the two species and the suspected hybrid (Pl. II). The length of the bud varied from 11.3 cm. for the globose to 24.3 cm. for the oblong, and the width from 6.4 cm. to 11.6 cm.

Bracts of seven clones were either not revolute or only slightly so. Five clones gave bracts that were revolute when fading. It was observed that bracts of female flowers and the first few bracts of the male flowers were more strongly resolute than the later ones. Bracts classified as slightly revolute tended to curl back in a lopsided manner. This tendency was observed only in the first few bracts, mostly of the female flowers.

Accurate color of the outer surfaces of different bracts obtained by matching with Ridgway's Color Standard and Nomenclature showed variations from deep red to dark violet. The color of the inner surface for each was paler. The extreme tips were greenish in some bracts, dark purple in others.

A remarkable characteristic of the bract of hybrids which makes most of them entirely different from those of pacol and abacá and strikingly similar to that of canton is the presence of streaks on both the outer and inner surfaces (Pl. II). These streaks varied in color and number and were totally absent in the bracts of three clones.

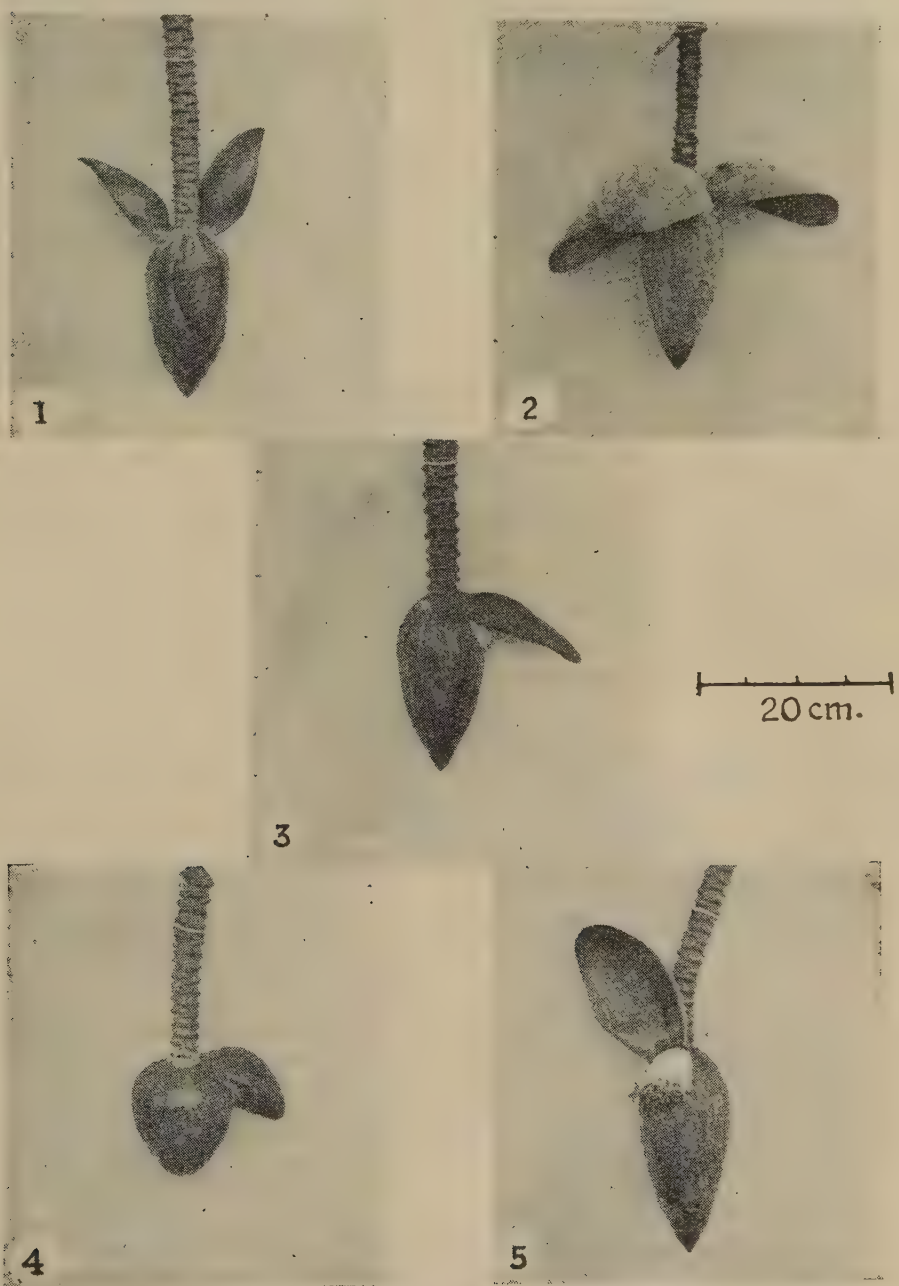

Fig. 1.—Male bud of abacá without waxy bloom.
Fig. 2.—Male bud of pacol with waxy bloom.
Fig. 3.—Male bud of pacol abacá with yellowish streaks on the bract.
Fig. 4.—Globose male bud of pacol abacá.
Fig. 5.—Male bud of canton with yellowish streaks.

The bracts of three hybrids were smooth like those of abacá; those of one hybrid were ribbed like those of pacol and the rest were slightly ribbed like most of canton's. Similarly, some were corrugated in the inner surface, others were slightly corrugated and the rest were not.

All clones lifted one to three bracts per day; one clone lifted no more than one bract a day while three clones lifted as many as three bracts a day. Lifting of the bracts occurred between six o'clock in the afternoon and seven o'clock in the morning. It was also noted that when the temperature was high during the day, the bracts commenced to lift at about six o'clock in the afternoon and when the day was cool and cloudy, the opening was delayed until the next morning, similar to the observations of Umali and Valdez (1951) in abacá, pacol and canton.

The length and width of the compound tepal varied according to the size of flower. Most had a pinkish or purplish tinge at the base and yellow or greenish yellow teeth; one clone had greenish cream compound tepals throughout.

Different clones varied in the relative length and width of free tepals. Some were as short as that of pacol and others were as long as that of canton. Not one of the free tepals was pinkish as in pacol.

All fruits of the hybrids did not set seeds even after pollination with abacá and pacol pollen grains. The bunch of fruits was classified as not compact, slightly compact or extremely compact (Pl. III). The number of hands per bunch ranged from 4 to 11, with an average of 6.4. The number of fruits per hand was equally variable with an average of 12.36 per hand.

Floral abnormalities

Each male and each female flower of abacá and pacol, including all other *Musa* species, possess only a compound tepal and a free tepal. There are six small tubular stamens within the inner whorl of the perianth lobes, but out of these, only five develop into staminodes in female flowers or reach full maturity and produce pollen in male flowers.

Some staminate flowers of the hybrids exhibited various interesting abnormalities, such as two or three compound tepals and two or three free tepals, the floral arrangement of which varied (Pl. IV,

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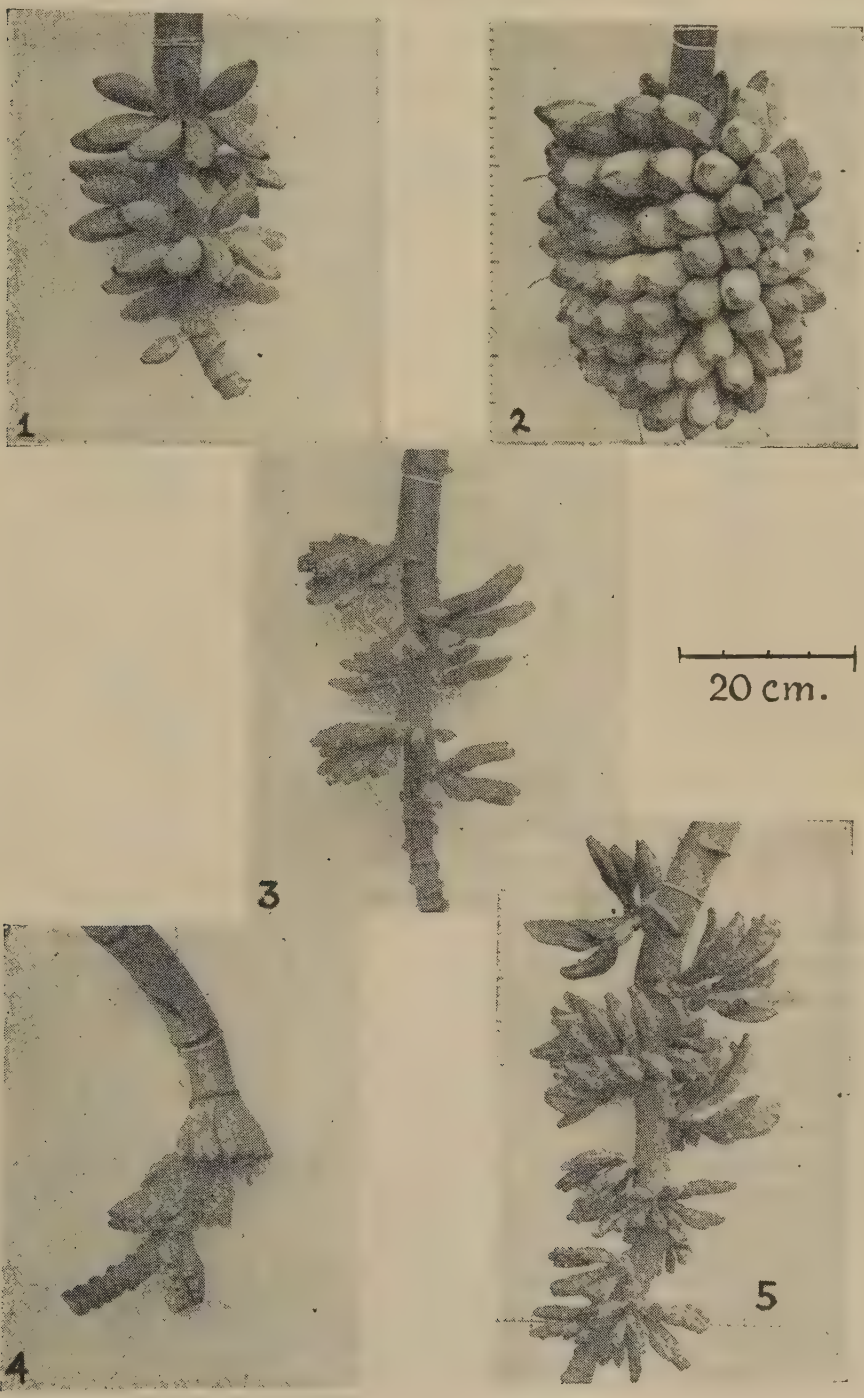


Fig. 1.—Bunch of mature fruits of abacá showing non-compactness.
Fig. 2.—Bunch of mature fruits of pacol showing compactness.
Fig. 3.—Bunch of mature fruits of pacol abacá showing compactness.
Fig. 4.—Bunch of mature fruits of pacol abacá showing extreme compactness.
Fig. 5.—Bunch of mature fruits of canton showing non-compactness.

figs. a, b, c and d). Some flowers also developed two or three non-functional pistils which sometimes differed in their rate of growth (Pl. IV, figs. e, f and g). Only two, three or four stamens developed in some (Pl. IV, figs. a, c, e and h). In some cases, delayed development of some staminate parts was noted (Pl. IV, fig. g), and in others, the development of the anthers was lopsided or asymmetrical (Pl. IV, fig. j).

Floral abnormalities in some flowers were limited to splitting of compound tepal (Pl. IV, figs. k and l), serration of free tepal (Pl. IV, fig. m), and abnormally thick or onionskin free tepal (Pl. IV, figs. n and o).

The frequency of abnormality was not great and occasionally occurred only in clones 9, 23, 24, 26, 28 and 36. Decayed development of some anthers was very frequent in clones 26 and 36.

No pistillate flower showed irregularities other than the splitting of compound tepals and serration of free tepals.

Not one of the abnormalities was observed in the staminate flowers of either pacol or abacá, but a number of flowers showing almost all irregularities were occasionally found in canton. This could be regarded as strong evidence of the hybridity of canton.

Relationship of the hybrids with abacá, pacol and canton

Table 1 which summarizes the relationships of plant characters of the hybrids and abacá, pacol and canton shows the great variability of the hybrids in most plant characters. Table 2 records the frequency of fifteen important morphological characters of the hybrids, which shows a clear picture of the distribution of variable characters of the hybrids. Majority of the clones showed all fifteen characters that are associated with canton. One clone, (Clone No. 28) showed fourteen characters possessed by pacol and another (Clone No. 25) showed close resemblance to abacá in all characters except in the behavior of the bracts when fading, the presence of purplish or pinkish coloration on the basal part of the compound tepal, the poor stooling capacity and the absence of black lining at the nether surface of the right lamina.

The characters manifested by the hybrids but which have not been observed in abacá, pacol or canton are the extremely pendulous inflorescence in three clones, globose and elongated male bud in two clones, greenish cream compound tepal (including teeth) in one

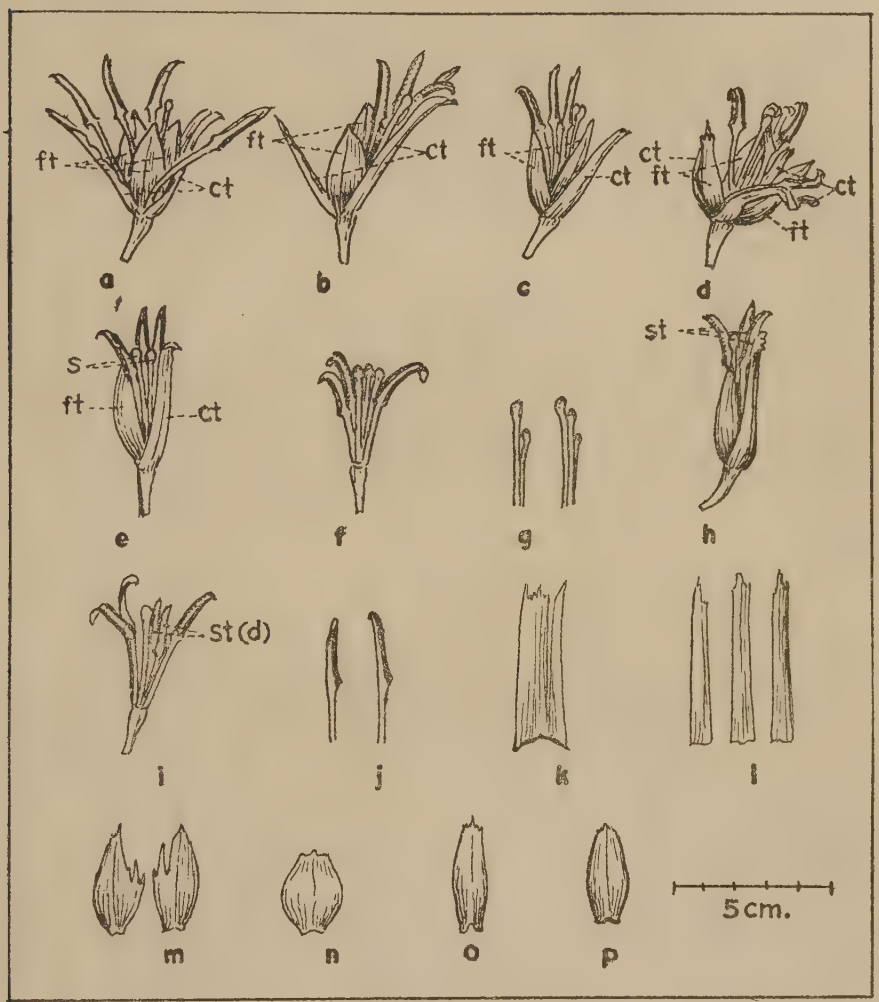


Fig. a.—Staminate flower with 3 free tepals (ft) and 2 compound tepals (ct).
Fig. b.—Staminate flower with 2 free tepals and 2 compound tepals.
Fig. c.—Staminate flower with 2 free tepals and 1 compound tepal.
Fig. d.—Staminate flower with 3 free tepals and 3 compound tepals.
Fig. e.—Staminate flower with 2 non-functional pistils (s).
Fig. f.—Staminate flower with 3 non-functional pistils.
Fig. g.—Unequal growth of reduplicated pistils.
Fig. h.—Staminate flower with 3 stamens (st).
Fig. i.—Two degenerated stamens [st(d)].
Fig. j.—Asymmetrical or lopsided anther development.
Fig. k.—Splitting of compound tepal.
Fig. l.—Complete separation of three sections of compound tepal.
Fig. m.—Serration of free tepal.
Fig. n.—Extra-thick free tepal.
Fig. o.—Long onionskin free tepal.
Fig. p.—Normal free tepal.

TABLE 1.—*Relationship of Plant Characters of Abacá, Pacol, Canton and Pacol-Abacá*

PLANT CHARACTERS	ABACA	PACOL	CANTON	PACOL-ABACA
1. *Pseudostem*				
Sheath color [a]	Pinkish, reddish or dull purplish [b]	Green or yellowish	Yellowish to pinkish or purplish	Green; dull or bright pinkish; dull or dark purplish
Glaucous or not	Not glaucous (shiny)	Glaucous	Slightly glaucous	Not glaucous, slightly glaucous or glaucous
2. *Leaf*				
Shape	Narrow, truncate at tip	Broad, truncate at tip	Intermediate	Broad, narrow or intermediate
Black lining	Present	Absent	Present	Present or absent
Midrib color	Green and purplish [b]	Green-yellowish	Pinkish or purplish	Green, pinkish or purplish
3. *Inflorescence*	Horizontal to sub-horizontal	Pendulous to sub-horizontal	Pendulous to sub-horizontal	Pendulous, sub-horizontal or horizontal
4. *Male bud shape*	Oblong-ovoid, blunt apex	Ovoid sub-acute to blunt apex	Ovoid, sub-acute to blunt apex	Ovoid, oblong ovoid or globose, acute to rounded apex
5. *Bract:*				
Behavior when fading	Not revolute	Revolute	Not revolute	Revolute or not revolute
Color of outer surface	Greenish brown to purplish brown	Lilac to vinaceous purple [b]	Dull Indian purple	Various shades of red or purple
Color of tip	Greenish to purplish	Greenish yellow	Greenish yellow	Greenish or dark purple
Streaks	Absent	Absent	Cream or yellowish streaks	Yellowish or reddish or cream streaks

TABLE 1 (continued)

PLANT CHARACTERS	ABACA	PACOL	CANTON	PACOL-ABACA
Color of inner surface	Paler than outer surface	Spinel pink to tournalin pink [b]	Dark vinaceous purple	Various shades of red or purple
Smooth or ribbed outer surface	Smooth and shiny	Ribbed	Smooth	Smooth or slightly ribbed
Smooth or corrugated inner surface	Smooth and shiny	Corrugated	Slightly corrugated	Smooth or slightly corrugated
No. lifting/day	1	2-3 or more	1-3	1-3
6. *Compound tepal:*				
Color of base	White or cream	White with pale to bright reddish purple	White to yellowish with reddish tinge	Yellowish with pinkish or purplish tinge
Color of teeth	Yellowish	Pale yellow to dark orange	Colorless or yellowish or greenish yellow	Yellow or greenish yellow
7. *Free tepal*	Translucent white	Translucent white or pinkish	Translucent white or pinkish	Translucent white
8. *Fruit bunch*	Not compact	Compact	Not compact	Compact or not compact

[a] Based on the basal part of the stalk.
[b] Description of parental varieties.

clone, and extremely compact bunch of fruit in two clones. Majority of the clones exhibit most of the characteristics of canton indicating that canton is a pacol-abacá hybrid (table 2).

TABLE 2.—*Frequency of plant character similarities of twelve pacol-abacá clones*

	ABACA-LIKE	PACOL-LIKE	CANTON-LIKE	COMMON IN ABACA PACOL	COMMON IN ABACA AND CANTON	COMMON IN ABACA AND CANTON	COMMON IN THE THREE	UNCOMMON IN THE THREE
Sheath color	4	1	—	—	7	—	—	—
Presence or absence of waxy bloom	2	1	9	—	—	—	—	—
Leaf shape	2	1	9	—	—	—	—	—
Midrib color	—	1	—	1	10	—	—	—
Position of inflorescence	4	—	—	—	—	5	—	3
Male bud shape	—	—	—	—	—	—	10	2
Bract								
Behavior when fading	3	5	4	—	—	—	—	—
Color	—	1	—	—	11	—	—	—
Presence or absence of streaks	—	—	9	3	—	—	—	—
Ribbed or unribbed	3	1	8	—	—	—	—	—
Corrugated or not	4	3	5	—	—	—	—	—
Color of compound tepal								
Basal part	—	—	—	—	—	11	—	1
Teeth	—	—	5	—	—	—	6	1
Color of free tepal	—	—	—	—	—	—	12	—
Fruit bunch compactness	—	5	—	—	5	—	—	2

Table 3 shows the average measurement of plant characters of abacá, pacol, pacol-abacá and canton. The hybrids indicate an intermediate resemblance to abacá and pacol and a close reasemblance

TABLE 3.—*Plant characters of abacá, pacol, pacol-abacá and canton*

TYPE	HEIGHT	STEM DIAMETER		MATURE LEAF		FRUITS (FEMALE FLOWERS)		BUD	
		50 cm. from base	100 cm. from base	Length	Width	No. of hands	No. of fingers/ hand	Length	Width
	cm.	*cm.*	*cm*	*cm.*	*cm.*			*cm.*	*cm.*
Abacá [a]	257	11.2	9.7	193.6	46.7	4.4	7.9	17.1	6.8
Pacol [b]	594	24.6	21.2	255	63.2	8.1	17.6	20.2	8.5
Pacol-abacá	363	19.1	16.5	243	66.5	6.4	12.4	18.6	8.6
Canton [c]	488	22.3	17.9	254	58.5	10.5	12.2	20.6	8.3

[a] Data obtained from Gorrez, 1955 (Unpublished thesis).
[b] Averages of 4 clones used in the breeding project.
[c] Averages of 4 clones studied.

to canton in height, stalk diameter and number of fruits per hand. The length and width of leaves and male buds and the number of hands per fruit did not show the same intermediate relation to abacá and pacol, but in general closely resembled pacol.

Mature bracts of pacol-abacá hybrids and canton are longer than those of abacá and pacol but intermediate in width (table 4). The number of male flowers per hand and the total length of flowers were much greater than those of abacá and almost similar to those of pacol and canton. A similar relationship was shown by the average measurement of the length of compound tepal.

Because it is generally smaller than the other three plants, abacá has smaller plant and floral characters except in the length of its free tepal. Free tepals of abacá are longer although narrower than those of pacol and almost equal in length to those of pacol-abacá and canton (table 4).

TABLE 4.—*Relative sizes of floral parts of abacá, pacol, pacol-abacá and canton*

TYPE	MATURE BRACTS		MALE FLOWERS					
					Compound Tepal		Free Tepal	
	Length	Width	No. per hand	Total length	Length	Width	Length	Width
	cm.	*cm.*		*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
Abacá [a]	10.7	6.3	9.3	4.7	3.8	—	3.0	1.2
Pacol [b]	13.9	13.1	18.2	6.2	4.4	1.2	2.2	1.7
Pacol-abacá	18.4	11.9	16.2	6.3	4.4	1.3	2.9	1.7
Canton [c]	16.3	7.0	15.3	6.1	4.5	1.1	3.3	1.7

[a] Data obtained from Gorrez, 1955 (Unpublished thesis).
[b] Average measurement of 4 clones used in the hybridization.
[c] Average measurement of 4 clones studied.

The female flowers of the hybrids could hardly be distinguished from those of abacá, pacol and canton.

The ovary of the flowers of the hybrids do not set seeds even after pollination. The angular, undeveloped fruits resemble those of canton.

The male flowers of the hybrids, like canton, can be distinguished from those of pacol and abacá by the absence or scarcity of pollen supply at the time of dehiscence. Some curl backwards, resembling those of canton, but others are straight and stiff like those of pacol. The short degenerate ovary of abacá male flowers is so strongly cemented together that the hands are intact at dehiscence. Pacol, pacol x abacá and canton flowers scatter at dehiscence.

Sheath and midrib coloration of abacá showed dominance over those of pacol.

Waxy bloom and coloration of the basal part of the compound tepal of pacol showed dominance over the absence of either in abacá.

Dominance and epistasis of other characters cannot be determined in the present study in view of heterozygosity of parental compositions and factors or gene interactions for the development of purely morphological or physiological characters.

II. FIBER

The primary interest in abacá breeding is to produce mosaic-resistant strains with good quality fibers. The crossing between abacá and pacol (*M. balbisiana* Colla) considerably affect the quality and quantity of the fiber because pacol, which is used to a limited extent for adulterating abacá fibers, is much weaker and softer than abacá fibers. It rarely produces a commercial grade higher than grade J2 (Superior Second No. 2) of abacá because the fiber is too weak to withstand the pressure of the knife used in the stripping of well-cleaned and high-grade abacá fibers (David, 1950).

The important fiber characteristics of pacol x abacá that were studied were tensile strength, fineness, breaking length or fiber stretch (important for cordage purposes), percentage of fiber extraction and length of fiber.

MATERIALS AND METHODS

The fibers of eight hybrid clones (clone nos. 4, 5, 9, 22, 24, 25, 26, & 28), which were segregates in important plant characters such as color of leaf sheaths, height and diameter of stalk, size and shape of leaves and presence of waxy bloom, were used in this study. Four clones each of pacol and canton were also studied in detail for their fiber characteristics and compared with the hybrids. Data on abacá fibers obtained from numerous sources were compared with those of the other fibers.

Mature stalks were tumbled after thorough study of their floral characteristics. The weight of each was determined and recorded. The "luknit" method of making "tuxies" was employed in this study. The "tuxies" were hand-stripped using a "hagutan."

In commerce the best grades of cleaning allowable with pacol and canton are J_2 K and M (fair) and the knife used had only 17

teeth to an inch (Fiber Inspection Am. Order No. 4, revised). This is to avoid too much loss of fiber due to breakage in the stripping machine. However, in this study a knife of 22 teeth to the inch was used to remove as much pulp as possible so that a better study of the fineness of the fiber could be made.

Fibers of two stalks of abacá of the Bongolanon variety were also stripped with the same knife for better comparison with the percentages of fiber extraction of the hybrid, pacol, canton and abacá.

After the stripping, the clean fibers were hung to dry. Five 20-cm. long samples of fiber strands taken at random from each leaf sheath bundle were used in determining the breaking strength and separate samples of ten 10-cm. long fiber strands, obtained from each leaf sheath bundle were used in determining the fineness of the fiber strand. Since abacá fibers from the basal, middle and end part of the leaf sheath differ in their physical properties (Albano, 1952), all samples were taken two feet from the basal end of the fiber strands.

In determining the breaking strength of each fiber strand with the Scott Tester IP-2 Tensilegraph machine (illustrated in Albano, 1952), a 2000-gram chart and a two-kilo carriage were used. The fiber samples were fastened one at a time to the jaws adjusted ten centimeters apart. After operating the machine anl noting the registered breaking load on the chart, the broken fibers were cut close to the sides of the jaws with a sharp razor blade and weighed in an analytical balance. The following formula (Botkin, Shires and Smith, 1955) was applied in computing for tensile strength (minimum length of a fiber in km. that will break under its own weight) in this study:

$$\text{Tensile strength} = \frac{\text{Breaking Load}}{\text{Weight of sample per centimeter}}$$

Fiber breaking length or strength for each sample was measured directly from the chart with a vernier caliper and the percentage of stretch for each was computed based on 10-centimeter length.

Fineness of the fiber strands for each leaf sheath as indicated by "Metric No." which is defined as the length of the fiber in kilometers per kilogram was computed by using the Dantzer and Roehrick formula:

$$\text{"Metric No." (in kilometers)} = \frac{10nl}{P}$$

where:

n = number of fibers
l = length of fiber in centimeters and
P = weight of whole in milligrams.

RESULTS AND DISCUSSION

The length of extracted fibers of eight hybrids ranged from 80 to 181 centimeters. Pacol-abacá clone no. 28 which is the tallest plant (6 meters) gave fibers that measured only 115 cm., which indicates that length of stalk alone does not determine the length of extractable fibers. Other factors such as tensile strength, and method and efficiency of extraction affect the length of extracted fiber. In this study the extracted fibers of the two abacá clones were longer (221 and 186 cm.) than any of the hybrids although those of abacá were shorter than some of the hybrid stalks, which supports the claim that tensile strength affects the length of extracted fiber. Pacol clones which had the tallest stalks among the groups showed much shorter fibers (71 to 128 cm.). Canton gave from 153 to 221 cm.

The percentage of fiber length was computed based on the length of the entire stalk. The pacol-abacá clones gave 19.18 per cent fiber length for clone no. 28 (the tallest hybrid) to 47.79 per cent for clone no. 22. The abacá clones gave 53.7, the highest among the groups. That for pacol ranged from 13.45 to 20.85 per cent, the lowest among the groups, and that for canton ranged from 33.26 to 46.04 per cent, closely approximating that of pacol-abacá except clone no. 28.

The actual percentages of fiber extraction based on the weight of the whole stalk for the hybrids ranged from .09 to .04 per cent. A comparison with the actual percentage of extraction of the two Bongolanon clones which are .45 and .33 per cent however, shows that the low percentages were probably due to the low efficiency of the stripper. Stripping fibers by hand needs both skill and experience to obtain the maximum length and amount of fibers from the tuxies. Abacá fibers consist from two to three per cent of the stalk, depending upon the variety and efficiency of extraction. The percentage of fiber extraction was adjusted based on two per cent in

abacá. The adjusted percentage of fiber extraction for the hybrids ranged from .55 to 2.4 per cent, while those for pacol ranged from .29 to .65 per cent, which are much lower than the 0.9 to 1.5 per cent range for pacol as reported by David (1950). The percentages for four canton clones, .87 to 1.46 per cent, are close to those of most of the hybrids.

In general, the tensile strength in kilometers of fibers for the pacol-abacá, pacol and canton clones indicate high variability within each clone. Fibers from the outer and inner leaf sheaths are generally weaker than those from the middle leaf sheaths, which corroborates the findings of Albano (1952). Espino (1915) explained that the brittleness of the fibers from outer leaf sheaths was due to the presence of a great number of stigmata, whereas the weakness of the strands from the innermost sheaths was due to the underdeveloped cell walls.

The average values for each clone also show much variability within the hybrid, pacol and canton groups (table 5). The average tensile strength of the hybrids varied from 18.77 ± 1.20 for clone no. 25 to 36.90 ± 3.2 for clone no. 22. It was surprising that clone no. 25 which was very similar to abacá in plant characters had the weakest fiber. Pacol showed less variability (24.00 ± 1.50 to 30.13 ± 1.79) and canton was almost uniform (29.76 ± 1.86 to 31.78 ± 2.00). Known varieties of abacá differ considerably in the tensile strength of fibers (Robinson and Johnson, 1953). Even the strength of cotton lint shows appreciable variation among individual plants of the same variety (Hancock, 1944).

A number of highly significant differences occurred within the clones of pacol-abacá, most of which resulted in the comparison of clone nos. 25 and 28 with other clones (table 5a). Clone no. 25 was very similar to abacá in plant characters while clone no. 28, to pacol. Excluding these two extreme segregates, only four significant differences (at five per cent level) remain within the pacol-abacá group. Clone nos. 22, 5 and 24 were statistically similar in tensile strength and appeared to be the best of the group.

Table 5a shows no significant difference in tensile strength between several clones of the hybrid and canton and pacol clone nos. 2 and 3.

TABLE 5.—*Average tensile strength, fineness and stretch of pacol-abacá, pacol and canton clones*

TYPE	CLONE NO.	TENSILE STRENGTH	FINENESS	STRETCH
		km.	*km.*	*per cent*
Pacol-abacá	4	29.65 ± 1.19	195.90 ± 7.74	1.343 ± .068
	5	34.29 ± 1.85	192.83 ± 13.19	1.193 ± .073
	9	29.76 ± 1.39	104.66 ± 7.72	1.319 ± .106
	22	36.90 ± 3.29	216.47 ± 11.26	1.268 ± .070
	24	34.52 ± 1.51	191.86 ± 13.11	1.064 ± .050
	25	18.77 ± 1.20	235.23 ± 11.87	0.930 ± .063
	26	31.32 ± 1.78	147.84 ± 6.45	1.609 ± .074
	28	25.15 ± 1.44	118.75 ± 10.04	1.142 ± .079
Average		30.04	175.44	1.234
Pacol	1	24.38 ± 1.98	[a]	1.110 ± .064
	2	29.10 ± 1.73	200.19 ± 10.39	1.036 ± .044
	3	30.13 ± 1.79	130.65 ± 7.10	1.362 ± .087
	4	24.00 ± 1.50	277.05 ± 16.82	1.095 ± .049
Average		26.91	202.63	1.150
Canton	1	31.78 ± 2.00	187.43 ± 9.35	1.481 ± .096
	2	29.76 ± 1.86	152.28 ± 8.48	[a]
	3	31.53 ± 2.74	148.47 ± 8.29	1.170 ± .072
	4	30.04 ± 2.04	93.44 ± 4.61	1.189 ± .090
Average		30.78	145.41	1.280

[a] Discarded due to some error in getting the data.

In general the fibers from the outer and inner leaf sheaths were finer than those from the middle leaf sheaths as they were similarly weaker in tensile strength. The averages for each clone also showed much variability.

Hybrid clone no. 25, the lowest in tensile strength, had the finest fibers, giving 235.23 ± 11.87 kilometers. The coarsest fibers were those of hybrid clone no. 9, followed by hybrid clone no. 28 which strikingly resembles pacol in morphological characters. Pacol was very variable in fineness and canton showed more variability (93.44 ± 4.61 to 187.43 ± 9.35 kilometers) in fineness than in tensile strength.

Comparisons of *t* values of means show more highly significant differences within and between the hybrid, pacol and canton groups (table 5b). Clone nos. 28 and 9 were significantly coarser than all others while clone nos. 22 and 25 were significantly the finest.

TABLE 5a.—*Values of t for comparison of means (tensile strength of fibers of pacol-abacá hybrids, pacol and canton)*

		PACOL-ABACA CLONE NO.							PACOL CLONE NO.			CANTON CLONE NO.			
		b	24	4	9	22	25	28	1	2	3	4	1	2	3	4
Pacol-abacá	26	1.15	1.35	.78	.69	2.38 [a]	5.85 [b]	1.88	2.61 [a]	.89	.47	3.14 [b]	.17	.61	.06	.47
"	5		.09	2.12 [a]	1.96	.69	7.05 [b]	3.91 [b]	3.66 [b]	2.05 [a]	1.62	4.32 [b]	.92	1.73	.86	1.55
"	25			2.54 [a]	2.31 [a]	.66	8.16 [b]	4.85 [b]	4.07 [b]	2.36 [a]	1.87	4.92 [b]	1.09	1.98	.96	1.76
"	4				.06	2.08 [a]	6.47 [b]	2.69 [a]	2.29 [a]	.26	.22	2.97 [b]	1.16	.49	.63	.17
"	9					1.70	6.01 [b]	2.52 [a]	2.23 [a]	.29	.16	2.82 [b]	.83	0	.58	.11
"	22						5.33 [b]	3.46 [b]	3.26 [b]	2.15 [a]	1.81	3.57 [b]	1.33	1.89	1.25	1.77
"	25							3.78 [b]	2.42 [a]	4.92 [b]	5.28 [b]	2.72 [a]	5.58 [b]	4.95 [b]	4.27 [b]	4.78 [b]
"	28								.33	1.88	2.32 [a]	.58	2.85 [b]	2.08 [a]	2.13 [a]	2.07 [a]
Pacol	1									1.79	2.15 [a]	.15	2.63 [a]	1.98	2.12 [a]	1.99
"	2										.69	2.23 [a]	1.02	.26	.77	.35
"	3											2.63 [a]	.62	.15	.43	.03
"	4												3.11 [b]	2.41 [a]	2.41 [a]	2.38 [a]
Canton	1													.74	.07	.61
"	2														.55	.10
"	3															.45

[a] Significant at .05 level.
[b] Significant at .01 level.

TABLE 5b.—*Values of t for comparison of means (metric no. in km. of pacol-abacá hybrids, pacol, and canton)*

		PACOL-ABACA CLONE NO.							PACOL CLONE NO.			CANTON CLONE NO.			
		5	24	4	9	22	25	28	2	3	4	1	2	3	4
Pacol-abacá	26	3.07 [b]	3.02 [b]	4.76 [b]	4.30 [b]	5.29 [b]	6.48 [b]	2.44 [a]	4.28 [b]	1.79	7.18 [b]	3.63 [b]	.42	.06	6.86 [b]
"	5		.52	.20	5.77 [b]	.56	2.39 [a]	4.48 [b]	.44	4.15 [b]	3.94 [b]	.33	2.59 [a]	2.91 [b]	7.14 [b]
"	24			.27	5.74 [b]	1.43	2.46 [a]	4.43 [b]	.49	4.11 [b]	3.99 [b]	.28	2.54 [a]	2.30 [b]	7.08 [b]
"	4				8.36 [b]	1.55	2.77 [b]	4.80 [b]	.33	6.23 [b]	4.39 [b]	.69	3.79 [b]	4.18 [b]	11.39 [b]
"	9					8.20 [b]	9.23 [b]	1.11	5.85 [b]	2.48 [a]	9.32 [b]	6.83 [b]	4.16 [b]	3.87 [b]	1.24
"	22						1.15	6.49 [b]	1.06	6.45 [b]	2.99 [b]	1.98	4.56 [b]	4.87 [b]	10.11 [b]
"	25							7.51 [b]	2.23 [a]	7.57 [b]		4.23 [b]	7.80 [b]	6.00 [b]	11.18 [b]
"	28								5.65 [b]	.97	8.17 [a]	5.01 [b]	2.57 [a]	2.28 [a]	2.29 [a]
Pacol	2									5.54 [b]	3.89 [b]	.91	3.58 [b]	3.90 [b]	9.41 [b]
"	3										12.69 [b]	4.85 [b]	1.95	1.63	4.41 [b]
"	4											4.59 [b]	6.63 [b]	6.86 [b]	10.54 [b]
Canton	1												2.79 [a]	3.12 [b]	9.05 [b]
"	2													.32	6.10 [b]
"	3														5.84 [b]

[a] Significant at .05 level.
[b] Significant at .01 level.

Pacol, in comparison with the hybrids, showed both upper and lower extremes in fineness. Clone no. 3 (130.65 ± 7.10) was significantly coarser at five per cent level than five of the hybrid clones and clone no. 4 (277.05 ± 16.82) was significantly finer than the hybrid clone nos. 5, 24, 4 and 9.

The fibers of canton clones were significantly coarser than most of the hybrid clones except nos. 9 and 28. Many highly significant differences in both upper and lower extremes were noted between pacol and canton clones.

Expressed in per cent, the breaking length or stretch of pacol-abacá, pacol and canton showed much variability within clones but no distinct trend was apparent to show any relation between breaking length and leaf sheath number.

Clone no. 25 which had the weakest fibers gave the lowest stretch (.930 ± .063 per cent) among the hybrid clones, while clone no. 26 gave the highest stretch with 1.609 ± .074 per cent. Appreciable variability is likewise notable between the means of pacol and canton clones.

Clone no. 26 was significantly the best (greatest) and clone no. 25, the poorest (lowest) in breaking stretch.

Comparisons between the hybrids, pacol and canton show that there is no significant difference between the best clones of the hybrids and canton, whereas the best clone of pacol was significantly inferior to the best of the hybrid (table 5c).

Some of the hybrid fibers had a characteristic musty smell which is quite different from the fresh clean smell of abacá. The fibers were light in weight and very soft. The tips tended to be curly and fluffy.

Upon examination of fiber strands under the microscope, no appreciable difference was noted between those of abacá, pacol, canton and the hybrids. There were a few silicified cells which looked like small bricks, observed by Aldaba (1926) in canton fibers. This was because the fibers of the hybrids were well-cleaned.

The summary of the relationship of fiber length and percentage of fiber extraction of the hybrids and abacá, pacol and canton are shown in table 6. Abacá had the longest fibers (2.03 meters, or 53.8 per cent of the stalk length) and pacol, the shortest (0.94 meters or 16.81 per cent of the stalk length). Pacol-abacá and canton were intermediate, the former having 1.38 meters or 37.03 per cent

TABLE 5c.—*Values of t for comparison of means (fiber stretch of pacol-abacá hybrids, pacol and canton)*

		PACOL-ABACA CLONE NO.							PACOL CLONE NO.				CANTON CLONE NO.		
		5	24	4	9	2	25	28	1	2	3	4	1	3	4
Pacol-abacá	26	3.98 [b]	6.03 [b]	2.66 [a]	2.23 [a]	3.33 [b]	7.38 [b]	4.31 [b]	5.07 [b]	6.60 [b]	2.16 [a]	5.76 [b]	1.04	4.22 [b]	3.56 [b]
"	5		1.46	1.49	.97	.74	2.77 [b]	.48	.86	1.84	1.49	1.12	2.38 [a]	.23	.04
"	24			3.26 [b]	2.15 [a]	2.35 [a]	1.66	.82	.56	.42	2.96 [b]	.40	3.80 [b]	1.19	1.19
"	4				.19	.76	4.46 [b]	1.93	2.48 [a]	3.76 [b]	.18	2.95 [b]	1.26	1.73	1.35
						.39	3.14 [b]	1.35	1.68	2.44 [a]	.31	1.92	1.13	1.16	.93
"	22						3.63 [b]	1.20	1.68	2.79 [b]	.83	2.03 [a]	1.78	.97	.69
"	25							2.10 [a]	2.02	1.38	4.03 [b]	2.07 [a]	4.78 [b]	2.51 [a]	2.34 [a]
"	28								.31	1.16	1.87	.51	2.72 [b]	.27	.39
Pacol	1									1.06	2.35 [a]	1.95	3.83 [b]	.62	.70
"	2										3.33 [b]	.88	4.17 [b]	1.58	1.51
"	3											2.68 [a]	.92	1.69	1.38
"	4												3.56 [b]	.86	2.83 [b]
Canton	1													2.57 [a]	2.19 [a]
"	3														1.62

[a] Significant at .05 level.
[b] Significant at .01 level.

of the stalk length and the latter, 1.86 meters or 40.69 per cent of the stalk length.

TABLE 6.—*Relationship of fiber length and percentage of fiber extraction of pacol-abacá, abacá, pacol and canton* [a]

TYPE	LENGTH OF STALK	LENGTH OF FIBER EXTRACTED	FIBER LENGTH / STALK LENGTH	WEIGHT OF STALK	WEIGHT OF FIBER EXTRACTED	ACTUAL PERCENTAGE EXTRACTION	ADJUSTED % EXTRACTION [b]
	cm.	*cm.*	*per cent*	*kg.*	*gm.*		
Pacol-abacá	375.00	138.87	37.03	42.88	100.14	.234	1.12
Abacá	378.00	203.50	53.80	33.00	134.75	.408	2.00
Pacol	563.75	94.75	16.81	65.00	45.90	.070	0.34
Canton	457.75	186.25	40.69	64.75	139.17	.215	1.05

[a] All figures are averages.
[b] Computed based on 2 per cent for abacá.

The mean adjusted percentages of extraction showed that abacá has the most extractable fibers and pacol, the least. Pacol-abacá and canton were intermediates. It is interesting to note that hybrid clone no. 4 with an adjusted percentage extraction of 2.4 ranks with abacá.

The fibers of most of the hybrid clones and those of pacol and canton were fluffy with a characteristic musty smell and were lighter than those of abacá.

The average tensile strength, fineness and breaking length of fibers of abacá, pacol-abacá, pacol and canton are shown in table 7. The mean value for tensile strength was obtained from Baliguas (1955) in which seven abacá varieties were studied. The mean value for fineness was computed from Carag (1952) in which 14 stalks of abacá varieties, Samurong Pula and Samurong Puti, were used and the average value for stretch was computed from the percentage of stretch of all grades of abacá as summarized by Robinson and Johnson (1953).

TABLE 7.—*Average tensile strength, fineness and fiber stretch of abacá, pacol-abacá, pacol and canton*

TYPE	TENSILE STRENGTH	FINENESS (Metric No.)	STRETCH (Per cent)
Abacá	85.10 [a]	70.73 [b]	2.61 [c]
Pacol × Abacá	30.04	175.44	1.23
Pacol	26.91	202.63	1.15
Canton	30.78	145.41	1.28

The averages show that abacá fibers are coarser, longer in breaking stretch and greater in tensile strength than those of pacol-abacá, pacol and canton. Pacol has the finest and the weakest fiber and has a lesser average percentage of stretch than pacol-abacá and canton. The average values for the hybrids and canton show that both are intermediate to pacol and abacá in tensile strength, fineness and stretch, although the values are below the arithmetic averages of the two species.

Self and Henderson (1954) in a study of the inheritance of tensile strength in a cross between two upland cotton varieties found that the F_1 was essentially intermediate between the parents although the mean was somewhat below the arithmetic average of the parents. Ware and Herrell (1944) concluded that the strength of lint in cotton is quantitative in inheritance and that there is essentially an absence of dominance in crosses.

The study on fibers shows that selection for high percentage of extractable fibers equal to that of good abacá varieties can be made among the segregating clones of the F_1 progeny. Selection for high tensile strength, desirable coarseness for cordage purposes, and high percentage of breaking length, however, would be unsatisfactory, taking abacá as the standard. The best hybrids from the standpoint of tensile strength were equal only to the best pacol and canton clones. The backcross method of breeding should be adopted to incorporate both disease resistance and tensile strength of fibers into the hybrid.

III. CYTOLOGY

The high degree of sterility of the hybrid is a stumbling block in the backcrossing program for disease resistance. Abacá (*M. textilis* Née) having $2n = 20$ when crossed with pacol (*M. balbisiana*) which has $2n = 22$ would give a progeny with 21 chromosomes (Valmayor *et al.*, 1956). The state of chromosome imbalance in the hybrid nucleus which has a ten-chromosome complement from abacá and an eleven-chromosome complement from pacol presents a problem of genome complexes.

Backcrossing the hybrids with different abacá varieties as pollen parents was attempted, following the report of Handley (1953) that the highly sterile cross between two sorghum species set some seeds when used as the female parent. It was believed that the development in the hybrids of some aposporous female gametes as in the

sorghum hybrid would result in the formation of fertile ovules which could be fertilized by abacá pollen. Pollen grains of varieties Samu-Tangongon, Maguindanao, and Expt. Sta. Nos. 1, 2 and 3 [3] were rong Pula,, Samurong Puti, Bulao, Itom, Bongolanon, Binagacay, used. Applications of pollen grains on the hybrids were done at different times of the day from morning till afternoon to cover the duration of stigmatic receptivity of the hybrids. The pollination involved 92 hands with more than 1,000 flowers. Not one fruit set seeds, which indicates strongly that the hybrids studied are completely female sterile.

Very few pollen grains were produced by some hybrid clones and this occasionally occurred only in a few of their staminate flowers. These pollen grains found to be full, rounded and forming pollen tubes when examined under the microscope, were tried on different varieties of abacá. It was thought possible that among these few pollen grains of the hybrids, a few are either normal with a complete genome of ten chromosomes or an unreduced chromosome number of 21. Sterile plants occasionally produce unreduced pollen grains that are sterile. Thus, Cheesman (1932) successfully crossed a fertile variety of *Musa malaccensis* Ridle and the sterile Gros Michel with the former as seed parent, and he believed that the few seeds produced on *Musa malaccensis* were due to some unreduced pollen of Gros Michel. Many of the backcrosses failed to set plump seeds on abacá. One cross with Expt. Sta. No. 3 fortunately set a number of black plump seeds. The seeds were planted immediately after harvest on March 12, 1957. Several seeds germinated in the second week of May.

Cytological studies of pacol, abacá and canton have been conducted by Valmayor *et al.* (1956). Both abacá and pacol were found to be fertile diploids with normal meiosis. Canton, the suspected natural cross of abacá and pacol, was found to possess 10 pairs of chromosomes and appears to be regular in early meiosis. Cell breakdown in canton begins immediately following first meiotic division and results in aborted spore quartets and complete sterility of the pollen. Valmayor *et al.* (1956) believe that this sterility is gene controlled.

This study of the F_1 hybrids determines the chromosome number, nature of sterility, and fertility relationship with pacol and abacá.

[3] Promising clones in the abacá plantation in College.

MATERIALS AND METHODS

Male buds of the hybrids were used after the completion of the studies on floral anatomy of each clone.

Male buds were picked between four and six o'clock in the afternoon since the materials picked at this time of the day supplied the best slides for meiotic studies (Cheesman, 1932; Valmayor, 1955). The materials were fixed in freshly prepared Carnoy's (or Farmer's) fixative. This solution was used followed by staining in acetocarmine. This combination was found suitable for cytological studies in Musa by Valmayor *et al.* (1956) and Dodds and Simmonds (1948). Dodds and Simmonds met considerable technical difficulty with the use of Carf, Navashin, Langlet and 2BE followed by crystal violet-iodine staining.

Since the male bud consists of overlapping bracts, each of which subtends a cluster of male flowers, the bracts were lifted one by one and each cluster of flowers secured separately. Each cluster was kept intact in the solution. This method was found advantageous because (1) the penetration of the fixative into the anthers was complete and rapid and (2) the search for the desired stage of pollen development was much easier, as all hands which were approximately a day older than the next, ontogenetically, were kept intact.

After 24 to 48 hours in the fixative, the materials were transferred to 70 per cent alcohol. The specimens were studied as soon as possible following fixation. Cytological examinations of the microsporocytes were made according to the standard acetocarmine smear technique described by Smith (1947).

Chromosome counts were made in all countable plates. The nature of chromosome pairing was studied at very early anaphase because the chromosomes exhibited considerable clumping at metaphase. The nature and frequency of occurrence of micronuclei or micro-cells in the quartets which could be considered as an index of irregularity of meiotic chromosome behavior (Love, 1951; Myers and LeRoy, 1938) were included in the cytological studies.

Cytological drawings were prepared with a Bausch and Lomb microscope using a 1.8-mm. (N.A. = 1.25) objective, Shillaber's immersion oil and camera lucida. Photomicrographs were taken by the Photographic Division of the College.

Temporary slides were made permanent following the standard schedule for making acetocarmine smears permanent as described by Buck (1935).

EXPERIMENTAL RESULTS

Meiosis

(a) *Resting stage and prophase I.* The young microsporocytes at resting stage were often observed to be compactly arranged, commonly polyhedral in shape with dense cytoplasm and well-defined nuclear membranes. Upon approaching prophase I, the microspore mother cells together with the tapetal cells separated from the parietal tissue *en masse* and then rounded off. The nuclear volume was very small compared to cell volume, being about one-fifteenth of the whole cell.

The most characteristic feature of the early prophase nucleus was the presence of a single, large, deeply-staining nucleolus. During the earlier stages of prophase in materials from two hybrid clones, an intermediate, not fully stained nucleolus-like body was observed. As the prophase advanced the chromonemata thickened somewhat but still appeared to be poorly stained and not sharply defined, even at late pachytene, diplotene and diakinesis.

In two of the materials used (Clone nos. 6 and 36) which never produced pollen grains, meiosis did not proceed beyond the prophase stage. The cell membrane and dense cytoplasm broke down, leading to complete abortion of the pollen mother cells. Aborted microsporocytes left irregular masses with clearly stained nucleoli and some traces of chromosomal fragments. No study of the prophase in these cells was made because the chromosomes were not well stained and not clearly defined.

(b) *Metaphase I.* The prophase in other materials studied proceeded to metaphase I at the disappearance of the nuclear membrane and nucleolus. Two materials (Clones nos. 9 and 5, both producing scantly pollen grains occasionally) which showed slight differences in meiotic behavior were studied in detail from metaphase I to the development of pollen grains.

Metaphase I in both clones was characterized by considerable clumping and overcrowding at the center of the plate (Pl. V, fig. 1). In some cases, more frequently in clone no. 5 than in clone no. 9, chromosomes failed to congregate and were scattered in the equitorial plate (Pl. V, fig. 2).

As meiosis started to progress from the metaphase I to anaphase I, some chromosomes were observed to clump together, suggestive of multivalents. Cases of actual multivalent associations were observed most convincingly, however, at late anaphase I. All multivalents were in chains of I- or Y-shape; not a single ring was observed. Chains of as many as seven chromosomes were noted (Pl. V, fig. 3).

The nature of chromosome-pairing was closely studied at early anaphase I when chromosomes were just starting to move to opposite poles. The results are shown in table 8.

TABLE 8.—*Chromosome pairing in MI* [a] *of two pacol-abacá clones*

CLONE NO.	FREQUENCY	SYNAPTIC ASSOCIATION OF CHROMOSOMES				2N
		Univalent	Bivalent	Trivalent	Quadrivalent	
5	3	7	7	—	—	21
	1	9	6	—	—	21
	9	3	9	—	—	21
	4	5	8	—	—	21
	1	6	6	1	—	21
	1	4	7	1	—	21
	1	10	4	1	—	21
Average per P-M-C		4.85	7.85	0.11	—	—
9	3	7	7	—	—	21
	3	9	6	—	—	21
	1	7	4	2	—	21
	3	6	6	1	—	21
	1	5	5	2	—	21
	4	5	8	—	—	21
	1	5	6	—	1	21
	1	1	10	—	—	21
Average per P-M-C		5.82	6.70	.41	.06	21

[a] Metaphase I.

The table shows that all cells of clone nos. 9 and 5 studied had a somatic complement of 21 chromosomes. Most of the P-M-C's (pollen mother cell) of clone no. 5 had three univalents and nine bivalents. As many as 10 univalents and as few as four bivalents were observed. Three trivalents were observed with different numbers of univalents and bivalents. Clone no. 9 exhibited from one to nine univalents and from four to 10 bivalents. Two trivalents occurred in two plates and a quadrivalent was associated with five

univalents and six bivalents. The averages per P-M-C for the two clones show that clone no. 5 has less univalents, more bivalents and less multivalents than clone no. 9.

In microspore mother cells exhibiting failure of aggregation, chromosomes singly or in groups were usually found to be widely scattered or some were located far from the others in the equatorial line. In such cases, spindle fibers were observed to be ill-defined. "Solitary" chromosomes were usually associated with separate spindle fibers resulting in a great number of striae that were not parallel and seemed to cross one another (Pl. V, fig. 2). Microsporocytes that had clumping chromosomes on the equatorial line were not entirely free from morphological abnormalities in the spindles. The spindles sometimes were asymetrical or crooked (Pl. V, figs. 4 and 5). At times they appeared very broad, but in most cases were very compact and narrow resulting in unsynchronized migration of the chromosomes to the poles.

(c) *Anaphase I.* Anaphase I showed a number of meiotic irregularities, the most common of which were laggards and unequal distribution of chromosomes (Pl. V, fig. 5) in both clones, and bridges in clone no. 5. In many cases, bivalents lagged. Attempts to study the morphology of chromosomes revealed that lagging bivalents were most probably non-homologous pairs as suggested by the difference in size and shape of the chromosome (Pl. V, fig. 6). Very frequently, these non-homologous pairs failed to disjoin at heterotypic division and migrated to either pole wholly. In most plates splitting of univalents occurred at anaphase I (Pl. V, fig. 7), but majority of them remained intact as dyad chromosomes. Aside from two cases of trivalents that failed to disjoin and migrated wholly to one pole, no further observation on the disjunction of multivalents was made.

The nature and frequency of different abnormalities at anaphase I in hybrid clone nos. 5 and 9 are shown in table 9. Hybrid clone nos. 5 and 9 were essentially the same in the frequency of laggards, multivalents and unsynchronized movement of daughter chromosomes toward opposite poles. Laggards were most common, occurring in 86.21 per cent and 90.00 per cent of the total number of P-M-C's observed for clone nos. 5 and 9, respectively; multivalents occurred in about one-fourth and unsynchronized chromosome movement, in one-tenth of the cells examined for both clones. Chro-

matid bridges were totally absent in clone no. 9 and abnormal spindle fibers were considerably less in clone no. 5.

TABLE 9.—*Nature and frequency of irregularities at anaphase I in two pacol-abacá clones*

		LAGGARDS	BRIDGES	MULTIVALENTS	UNSYNCHRONIZED MOVEMENT [a]	ABNORMAL SPINDLE	TOTAL NO. OF PMC OBSERVED
Clone No. 5	Frequency	75	25	20	9	7	87
	Percentage	86.21	28.73	22.98	10.34	8.04	
Clone No. 9	Frequency	36	—	10	4	19	40
	Percentage	90.00	—	25.00	10.00	47.50	

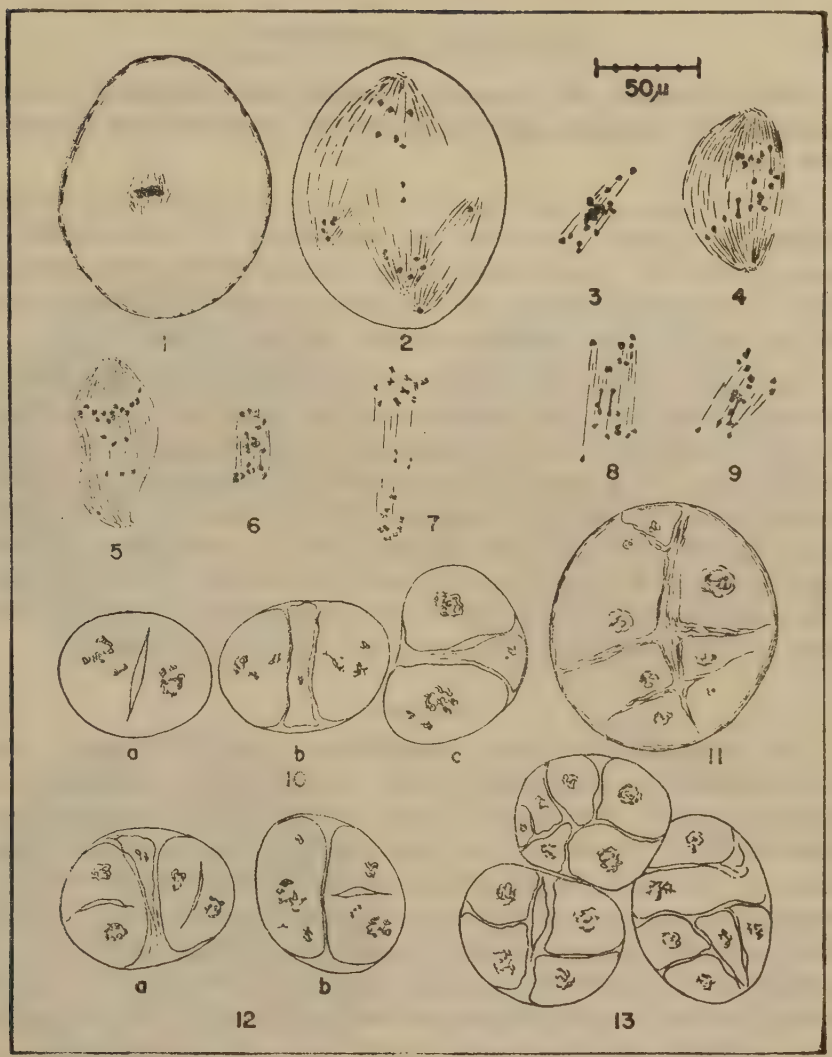
[a] Migration of chromosomes to the poles is one after another.

Bridges that occurred at anaphase had minute acentric fragments in some cases (Pl. V, figs. 8 and 9) but more often had no sign of fragments at all. As many as three bridges were observed in a single meiocyte.

Lagging chromosomes were frequently left out and not included in any of the telophase nuclei.

(d) *Division I.* After anaphase I cytokinesis started with the formation of slits on the middle of the plate. Majority of the cytokinesis observed in clone no. 5 were normal with the subsequent formation of two equally divided cells (Pl. V, fig. 10a). Two cases of abnormalities in the cytokinesis of clone no. 5 are illustrated in plate I, figs. 10b and 10c. Formation of secondary cell walls occurred; these, in turn, formed micro-cells in which laggards were often contained. Clone no. 9 showed more irregularity of cell wall formation due to the high frequency of failure of aggregation and subsequent formation of numerous spindle fibers associated with scattered chromosomes. Cytokinesis following division I was characterized by many branching secondary cell wall formations resulting in a considerable number of irregularly shaped micro-cells in the tetrad (Pl. V, fig. 11).

(e) *Division II.* After a brief interphase, homotypic division followed. The orientation of the spindles appeared to be irregular (Pl. V, fig. 12) resulting in quartets of all possible shapes. Microcells with "omitted" chromosomes usually underwent their own homotypic division, resulting in polyspory, the formation of numerous microspores varying in size and number (Pl. V, fig. 13).



Camera lucida drawings:

Fig. 1.—Metaphase I showing crowding and clumping of chromosomes.
Fig. 2.—Anaphase I showing evidences of failure of congression and association of separate spindle with separate groups of chromosomes.
Fig. 3.—Anaphase I with a multivalent of seven chromosomes.
Fig. 4.—Anaphase I with a trivalent and an asymetrical spindle.
Fig. 5.—Anaphase I with extremely unequal anaphasic distribution and abnormal spindle.
Fig. 6.—Anaphase I with laggards and two non-homologous pairs (unshaded).
Fig. 7.—Anaphase I with two splitting univalents.
Fig. 8.—Anaphase I with bridges and acentric fragments.
Fig. 9.—Anaphase I with a bridge and acentric fragment and a trivalent.
Fig. 10.—First division of clone No. 5: (a) normal, (b) and (c) abnormal, forming micro-cells with chromosomes "omitted" from the telophase nuclei.
Fig. 11.—First division of clone No. 9 showing secondary cell division as a result of non-congression and formation of complex spindle.
Fig. 12.—(a) Second division of clone No. 5 with irregular orientation of the spindle leading to an irregularly shaped quartet.
Fig. 12.—(b) Anaphase II showing random distribution of chromosomes.
Fig. 13.—Irregularly shaped quartets with micro-cells.

Plate VI shows the process of meiosis from anaphase I to the production of polyspores and small, empty, shrivelled and irregular pollen grains.

(f) *Frequency of micronuclei.* The frequency of micronuclei (which were mostly separated as micro-cells) of the quartets is shown in table 10. Counts were made in 245 P-M-C's from clone no. 5 and in 120 from clone no. 9. An odd number of micro-cells was noted suggesting that some micro-nuclei did not divide.

The table shows that more than one-half of the quartets of clone no. 5 had only one micronucleus or micro-cell and 4.89 per cent were irregularly shaped quartets not containing any micronucleus. Clone no. 9 had more micronuclei per quartet, 1, 2, 3 and 4 per quartet being the most frequent. This is because of the many cases of failure of congression observed, the spindle fiber abnormality and subsequent irregular cytokinesis in clone no. 9. Unlike clone no. 5, quartets without any micronucleus were not evident. In both clones, as many as eight micronuclei per quartet were noted.

DISCUSSION

The irregular anaphasic chromosome distribution varied from 4-17 (irrigular) to the normal, 10-11. Sharp (1943) states that irregular anaphasic distribution is one of the results of partial asynapsis. Wilson (1946b) noted marked asynapsis in two diploid clones, one of which was a Philippine unidentified variety (*M. balbisiana*). Asynapsis also occurred in some triploid clones (Wilson, 1946a). In the latter, extreme asynapsis was observed where 33 chromosomes failed to pair and appeared as univalents. Some of the spindle fiber irregularities described in this study were also observed by Dodds and Simmonds (1948) in sterile diploid hybrids of Musa. Working on the same diploid *Musa* hybrids, they observed the occurrence of univalents, bivalents and multivalents which, however, were either convergent or linear.

No cases of multivalents were seen in abacá and pacol (Valmayor *et al.*, 1956) but translocation or interchanges of relatively large chromosomal segments must have taken place between the non-homologous chromosomes in one of the parental species in order that associations of more than two chromosomes could occur in the diploid pacol x abacá hybrids. The occurrence of as many as 10 univalents in the hybrid indicates that most of the chromosomes from the two parents are non-homologous in structure and perhaps have

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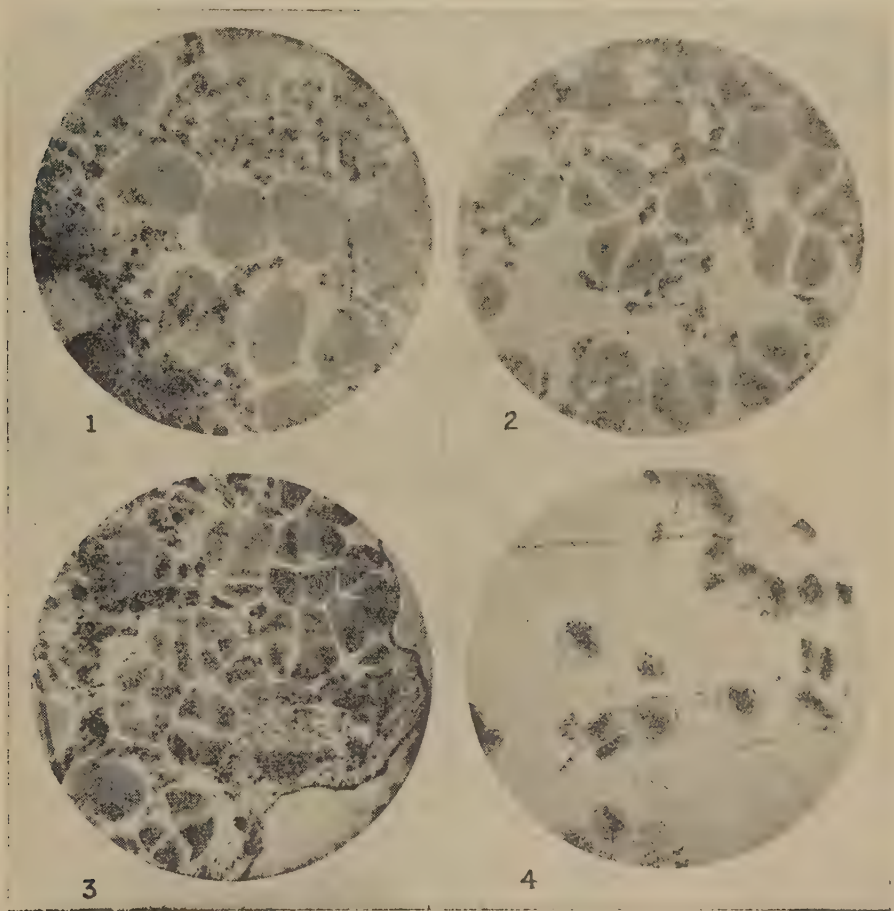

Photomicrographs:

Fig. 1.—Some cells with anaphase figures.
Fig. 2.—First division in clone no. 5.
Fig. 3.—Polyspores at the end of telophase II.
Fig. 4.—Aborted, shrivelled pollen grains.

TABLE 10.—*Frequency of micronuclei*[a] *in quartets of two pacol-abacá clones*

		NUMBER OF MICRONUCLEI PER QUARTET									TOTAL NO. OF PMC OBSERVED
		0[b]	1	2	3	4	5	6	7	8	
Clone No. 5	Frequency	12	145	46	25	11	3	1	1	1	245
	Percentage	4.89	59.18	18.78	10.20	4.49	1.23	.41	.41	.41	
Clone No. 9	Frequency	0	24	30	29	20	11	4	1	1	120
	Percentage	—	20.00	25.00	24.17	16.66	9.17	3.33	.83	.83	

[a] Most were separated as micro-cells.
[b] Irregularly shaped quartets.

considerably wide genic differences, indicating diverse genomic compositions.

Bivalents made up of non-homologues are not uncommon in inter-specific hybrids and often fail to disjoin in the heterotypic division (Feng, 1934; Li *et al.*, 1954). McClintock as cited by Sax (1935) suggested that non-homologous prophase pairing is caused by a mechanism in which chromosomes start their pairing by a force demanding two by two associations which can supersede that of homologous attraction when these forces are not working in unison.

In the two clones of hybrids studied, chromatid bridges occurred in one and not in the other at anaphase I. These bridges with acentric fragments are evidences of paracentric inversions that took place. Sharp (1943) and Sinnott *et al.* (1950) state that crossing-over within the inverted sections will produce a fairly high degree of sterility. The occurrence of anaphase bridges and fragments in hybrid clone no. 5, however, should not mainly account for the high degree of sterility of the particular hybrid. The significance of bridges and fragments as causes of sterility in species hybrids is considerably reduced by the discovery that these configurations are common in some fertile species (Stebbins, 1945). The high sterility of both clones should rather be explained by the state of imbalance in the chromosome complement due to the absence of homology in chromosomes which leads to asynapsis and irregular chromosome distribution. It is common knowledge that most of the hybrids composed of genomes that differ in chromosome number are sterile. Sharp (1943) states that wide genic differences accompany a hybrid of two species with different chromosome number. These genic differences must account for the many chromosomal abnormalities observed.

The absence of micro-cells in some irregularly shaped quartets that are otherwise normal probably resulted from more stable meiosis. This explained the occasional production of scanty pollen grains in some of the flowers of clone no. 9. Similar irregularly shaped quartets without any micronucleus may also have been produced by the hybrid. An examination of another cluster of flowers might prove this to be true.

The complete abortion of microspores at prophase in two of the clones studied can be explained only as a gene-controlled type of sterility.

Cytological Relation Between the Hybrid, Canton and "Minay"

The chromosome number and meiotic behavior of the hybrids studied do not coincide with that of canton. Valmayor *et al.* (1956) reported that canton has a genome of 10 chromosomes and that the first meiotic division proceeds regularly. "Minay", another supposedly derived hybrid of *M. textilis* and *M. balbisiana,* was found to possess a genome of 10 chromosomes. They explain that the high sterility of canton is gene controlled and that of minay is due to paracentric inversions. Both canton and minay were occasionally observed to produce a few pollen grains.

Despite the knowledge that hybrids between *M. textilis* and *M. balbisiana* must have 21 chromosomes, Valmayor *et al.* still believed that canton is a derived hybrid of the two species because it possesses characters that are intermediate to both. They advanced the opinion that canton probably is a natural backcross of the F_1 hybrid to abacá, thus explaining the 10 pairs of chromosomes. The possibility of a backcross occurring in nature is rather remote because the F_1 hybrids are highly sterile.

Despite the difference in chromosome number of the hybrids and canton and minay, there were some significant similarities in their chromosome behavior. The presence of bridges and fragments indicative of paracentric inversions taking place in clone no. 9 was observed in minay and the formation of micro-cells in both hybrid clones resembled that of the two suspected derived hybrids.

One possibility that may be considered to explain the difference in chromosome number of the hybrids and canton is the formation in pacol of ovules with only 10 chromosomes due to some abnormalities in the megasporogenesis. This ovule could have been fertilized with abacá pollen, thus producing a pacol-abacá plant with a somatic chromosome number of twenty. A study on chromosome morphology however, is necessary to determine the relationship between the hybrids and the supposedly derived hybrids. Only a complete knowledge of their karyotype can completely settle the question as to whether or not canton and minay originated from a natural cross between *Musa textilis* and *Musa balbisiana.*

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COPPER DEFICIENCY IN BICOL SOIL AS A POSSIBLE CAUSE OF THE CADANG-CADANG OF COCONUT[1]

J. R. Velasco

WITH SEVEN TEXT FIGURES

The cadang-cadang of coconut in Bicol Region has been estimated to have killed 5,527,000 trees, equivalent to a loss of 22 million pesos annually (Kent, 1953). Because of the enormity of this loss and the threat of its further increase, we should explore all means of solving the cadang-cadang problem at the earliest possible time.

The reaction of coconut to its environment is rather slow, and a treatment may have to be applied for some time before results could be expected. Thus, a treatment designed to influence the size or structure of leaves may show its effects about three years after the start of treatment. It will take more than three years to effect a turnover of the leaves in the crown, if there are, on the average forty leaves in it and one leaf is produced every month. Experiments on cadang-cadang should therefore be carefully planned. Whenever deliberation could replace a major part of experimentation, it should be adopted in order to shorten the time necessary to obtain pertinent results. In other words, in the cycle of gathering data in order to formulate an hypothesis and formulating an hypothesis in order to gather data, we should lean over to the latter aspect. The following discussions are an attempt to formulate an hypothesis on meagre data.

THE SYMPTOMS OF CADANG-CADANG

Leaves. There is a gradual shortening of successive leaves, the distal end of each leaf tending to be abruptly reduced. The leaf seems to be light and does not have the graceful arch observed in leaves of healthy trees. In the mild stage, the short leaves point in all directions looking like arms of a windmill. At a distance, the lower two-thirds of the leaves assume a shiny bronze appearance, while the upper one-third remains dark green. In the most severe stage, only a tuft of short upright green leaves remains on an otherwise bare stem (figs. 1-4).

[1] Central Experiment Station Contribution No. 871.

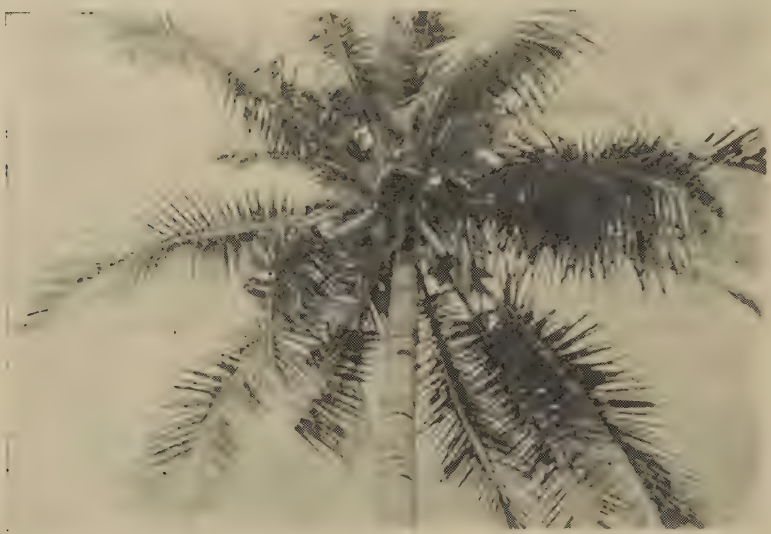

Fig. 1.—Trees about 30 ft. tall still fruiting but crown is light.

Fig. 2.—Inflorescence still present but no fruit formed. Leaves very much reduced in size and number.

Fig. 3.—No inflorescence noticeable; leaves greatly reduced.

Fig. 4.—Severely attacked.

Sometimes the leaflets are brittle and stiff and they have crinkled margins. In other cases, the leaflets are rather weak and they buckle at the middle.

The leaflets of the tenth youngest leaf, and those older, are evenly covered with yellow specks (2 x 3 mm.) which are translucent in transmitted light. Viewed at the lower surface of the leaflets, these specks are oily or water-soaked in reflected light. The specks tend to be elongated along the length of the leaflet. In old leaves they are numerous and tend to coalesce, forming irregular areas.

Fruits. At the mild stage of the disease, the fruits tend to be angular at the stigmatic end and fairly elongated (fig. 5). The fruit may have a band of dried or scarified epidermis running crosswise around the fruit. The number of nuts setting in a bunch diminishes abruptly, so that trees heavily loaded with fruits may on the contrary be considered diseased because no medium-sized fruits follow the heavy load of big, almost mature fruits. In most cases the heavily fruiting bunch buckles at the base and hangs limply from the trunk, while the light fruiting bunch remains short and inserted at the axil of the frond. In very severe cases, the tree ceases to produce inflorescence altogether.

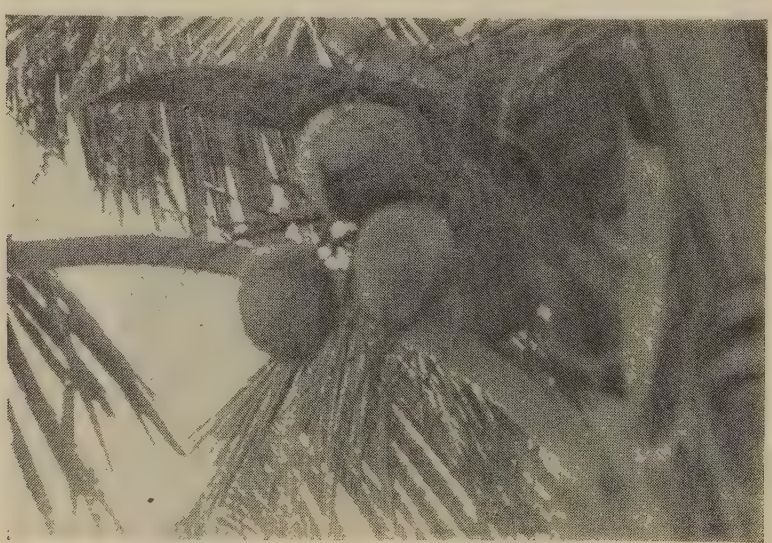

Fig. 5.—Fruit of trees mildly affected by cadang-cadang.

Trunk. Starting about a meter below the crown, the trunk is tapered distally. This may be a result of the greatly reduced foliage. This supposition finds confirmation in the tapering of heavily pruned buri palms (*Corypha elata* Roxb.) in Quezon province where buri leaves are used by farmers in weaving.

There are exceptions to the symptoms of cadang-cadang as described here. For example, some trees produce extremely weak leaves so that the arch they form is almost a semi-circle. A further manifestation of their weakness is their swaying at the slightest breeze. In some trees there is no noticeable bronzing or yellowing of the leaves. In others, the stigmatic point of fruits is abnormally flattened instead of pointed. And still in others, the trunk does not taper at all. About the only consistent symptoms are the water-soaked specks, the gradual decline, the failure to produce fruits and the ultimate death of the plant.

THE VIRUS THEORY OF CADANG-CADANG

The supposition that a virus is involved in the cadang-cadang disease was first advanced by Dr. G. O. Ocfemia in 1937. Having previously established the virus nature of a few diseases of abacá, Ocfemia was conceded more than a 50-50 chance that his diagnosis was right. The theory was presumably sustained by the repeated claims of one of Ocfemia's students (Celino, 1947) that he effected a transfer of the disease to other plants by means of pin-pricks. More recently, Ocfemia and Bustrillos (1957) found in electron micrographs of unpurified juices of cadang-cadang infected coconuts "numerous uniform particulate bodies of nearly spherical shape along with the plant debris. These bodies were observed (Pl. II, figs. 6, 7 and 8) in juices from cabbage and opened leaves . . . With these particles the writers believe that they have secured additional evidence that virus is the cause of the cadang-cadang disease of coconut." One shortcoming of the authors is that they failed to present a micrograph from the cabbage of healthy coconuts from the College. For all we know, the spherical bodies in the cabbage were mitochondria or tiny starch grains. In which case there would be just as much of them, if not more, in the cabbage of the healthy plants as in those of the diseased ones. But even if the observation were valid, it still would not clinch the argument for the virus theory. When the physiology of a plant is disturbed, some non-typical products of metabolism can be expected to occur. For example,

Reed and Dufrenoy (1942) have shown that profound cytological changes occur in green leaf cells and in growing points as an end result of zinc deficiency. Phenolic substances accumulate in cell vacuoles, although these effects are not necessarily specific to zinc deficiency.

Further support for the virus theory came from notable plant pathologists and virologists like Doctors Reinking, Vasudeva, Magee and Price who were recent visitors to this country.

It will be noted that other than Celino's claim which unfortunately has not been confirmed by other workers, there has been no direct evidence on the virus nature of cadang-cadang. We have relied largely on the claims of virus experts, who because of their extensive background, are credited with a diagnostic eye for the virus; but we have not considered their bias for their specialization.

It seems, therefore, pertinent at this point to re-examine the bases of the virus claim. The points were ably summarized by Kent (1953) when he said, "The theory of the virus nature of the disease rests on the similarity of symptoms, the absence of a microscopic causal agent, the apparently infectious nature of the disease, its spotty distribution, the presence in areas of 90 per cent infection of healthy trees with roots feeding in the same area as the diseased trees, and the tendency of the disease to spread from foci of infection (Ocfemia, 1937; Celino, 1947; Reinking, 1950; De Leon, 1951; De Leon and Bigornia, 1953; Calica and Bigornia, 1953)."

a. *Similarity of symptoms.* About the only consistent symptoms of cadang-cadang are the water-soaked specks, the gradual decline, the failure to produce fruits, and the ultimate death of the plant. These symptoms are unspecific and it holds true for any major disturbance in the plant, including nutritional disturbances and physical damage from typhoon.

b. *The absence of microscopic causal agent.* If we define a virus disease as any abnormality, the causal agent of which is not known, then we can class cadang-cadang among the virus diseases. However, the absence of a microscopic causal agent is just as strong an evidence for nutritional disturbance or unfavorable climatic conditions as it is for a virus.

c. *The apparently infectious nature of the disease.* The basis of this claim is the observation in epidemiological studies that once the disease starts in a coconut grove the percentage of diseased trees

gradually increases until nearly all the trees succumb to it. It is assumed that because some trees develop the disease after others did, the former must be infected from the latter. However, this line of argument impliedly denies the possibility of differential response among trees to a deleterious factor, which is not necessarily a virus.

The ultimate proof of the infectious nature of a disease is its experimental transmission from diseased to healthy plants.

d. *Its spotty distribution.* Spotty distribution is not evidence for or against the virus theory.

e. *The presence in areas of 90 per cent infection of healthy trees with roots feeding in the same area as the diseased trees.* This claim is apparently intended to rule out nutritional disturbance (deficiency or excess of a particular element) as an alternative to the virus theory. There seems to be an attempt here to ascribe the presence of healthy trees to individual variation or genetic resistance to a virus infection and to overlook the occurrence—which is equally probable—of individual or genetic variation as regards response of plants to nutrients in the soil. Apparently the proponent of this claim is reasoning too closely from results of rigidly controlled culture solution studies in which a major element, say, nitrogen is involved.

A more extended discussion of this point will be attempted in connection with copper deficiency.

f. *The tendency of the disease to spread from foci of infection.* This contention is apparently based on the fact that the first authentic report of cadang-cadang was on the island of San Miguel, off the coast of Albay province (Ocfemia, 1937). Subsequently it was observed in the coastal towns of Albay and thence it was supposed to have progressed to the interior towns. This was taken as an indication that the disease spreads from foci of infection. The claims of growers that the disease had been present in Nabua, Camarines Sur, as early as 1914, and in Calolbon, Catanduanes, since 1919, are apparently discounted.

The question at issue, it seems, is whether the disease actually started on San Miguel Island or the disease merely happened to be first discovered there.

It will be seen that all the bases of the virus theory do not stand close scrutiny.

RELATIONSHIP OF SOIL TYPE AND CADANG-CADANG

Let us correlate in a rough way the existence and severity of cadang-cadang with the type of soil in which the coconut is growing. In Laguna and Quezon, the soil that is widely distributed is a brown-to-red clay. Towards Naga, Camarines Sur, as the soil becomes sandy and it grades into gray to black, we notice borderline cases of cadang-cadang. The area betwen Pili, Camarines Sur, and Guinobatan, Albay, may be considered as a typical cadang-cadang area, and the typical soil here is a gray-to-black sandy loam. Beyond Daraga, Albay, on the road to Sorsogon, we notice a change in the texture and color of the soil. In kilometer numbers 557 to 590, the soil is a red, heavy clay similar to that found in Laguna and Quezon. Coincidentally, cadang-cadang is less severe in most of this area and in a large portion, it is not present at all. As we leave this mountainous red clay land towards the coastal towns of Sorsogon and Bacon, we notice a gradual reversion to the gray sandy soil, and an increasing severity of cadang-candang.

This observation gives the impression that something is primarily lacking in the gray-to-black soil. This lack is aggravated by the high rates of leaching in sand. We should expect some mitigation of the deficiency in the black clay soils that are found in spots, but there is little chance to confirm this, because most of these areas are in rice. The few trees which are astray in the rice fields, are suffering, partly on account of water-logging.

The vegetation in the Bicol Region reflects an insidious disturbance traceable to the soil. The disturbance is rather disconcerting because in general it is not patently manifest. It is what one would expect when an essential nutrient is in the borderline of deficiency. Young coconut trees may be growing and producing normally, then show the gradual decline leading to death. Citrus trees like those found in the Guinobatan Experiment Station may be dark green and producing profusely, but at about ten years of age they cease to produce and progressively decline. A few years later, the trees die one after another. Gumamela plants (*Hibiscus rosasinensis* Linn.) in Pili Agricultural School produce small, slightly cuffed leaves in the upper branches during the dry season. The margins and nether surface are purplish with anthocyanin pigment. Because the leaves are crowded at the tips of the slender wiry branches, the plant looks like a desert brush. The leaves on the lower branches are practically

normal-sized. During the rainy season, all the leaves on the plant are normal-sized and healthy.

It would have been better if those trees had exhibited typical deficiency symptoms, because diagnosis would be very much easier. But at borderline deficiency trees develop occasional mottling which can be misleading and which may be apparent only upon close scrutiny. What is more, they recover at certain seasons of the year.

In general, perennials do not readily show distinct symptoms of deficiency. Probabaly this is due to their ability to build up a certain amount of reserve which they can draw upon in times of stress. It is in the succulent annuals that symptoms show readily. Some annuals are very sensitive to nutrient deficiency and are suitable indicator plants. Some of the symptoms on susceptible plants are: (1) Tomatoes produce successively smaller leaves on reflexed rachises. The margins of the leaves are upturned, *i.e.*, the blades are cupped—very reminiscent of copper deficiency (fig. 6). (2) Culites (*Amaranthus viridis* Linn.) shows a gradual reduction in size

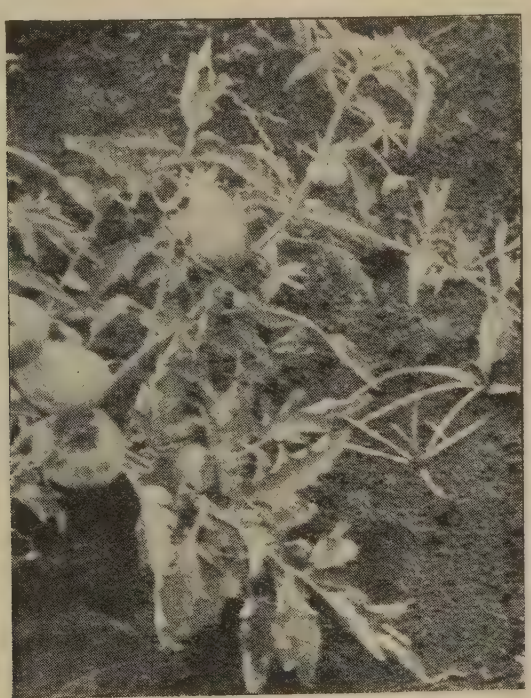

Fig. 6.—Tomato plant in Pili Agricultural School showing frizzled and cupped leaves.

of leaves. The midrib is reflexed. (3) Okra (*Abelmoschus esculentus* [Linn.] Moench.) produce cupped leaves, which dry up along the margins.

PRELIMINARY INDICATIONS OF COPPER DEFICIENCY IN SOME BICOL SOILS

A few samples of soil from widely spaced locations in the Bicol Region were brought back to the College of Agriculture for analysis. The symptoms in the field were not distinct enough to allow a decision between copper and zinc. To ascertain which is the deficient element, each of them was determined using the *Aspergillus niger* bio-assay method.[2] Zinc was sufficient and is of the same level as that in College soil. However, the average copper content of cadang-cadang soil is only 1.4 microgram per gram of soil (table 1).

TABLE 1.—*Copper content of soil from some coconut groves*

LOCATION	COLOR (moist)	TEXTURE (moist)	COPPER IN MICROGRAM PER GRAM OF SOIL
College, Laguna [a]	dark brown	clay	surface — 2.5
Guinayangan, Quezon	dark brown	sandy	surface — 0.44
Pili, Camarines Sur	black	loamy sand	surface — 1.65
Nasisi, Guinobatan, Albay	dark reddish brown	sandy	surface — 1.65
			subsoil — 1.60
Daraga, Albay (Km. 559)	dark reddish brown	sandy loam	surface — 1.14
			subsoil — 0.82
Bual, Daraga, Albay (Km. 572)	very dark brown	clay loam	surface — 1.61
			subsoil — 1.37
Bacon, Sorsogon	dark reddish brown	loamy sand	surface — 1.43
			subsoil — 1.43

[a] Only this soil is from the non-cadang-cadang area.

This is about half the amount in College soil. At a copper content of 0.6-1.5 microgram per gram of soil, cereals exhibited symptoms of borderline deficiency (Mulder, 1950). It is of interest to recall that the very dark brown, clay loam soil in Bual, Daraga, Albay is also low in copper; and yet, in general, the coconut trees here are healthy. There are only a few trees that show mild symptoms of cadang-cadang. Because the soil is heavy, the available copper may not be leached readily, hence, used more effectively by the plants. An equally probable reason is that iron, which may abound in the brown soil, can alleviate the bad effects of copper deficiency.

[2] Miss Alice Holaso and Mr. Eufracio Mamawal ran the tests.

Probably the functions of the copper-containing oxidases, like phenol oxidase, are assumed by the cytochromes or the iron-containing oxidases. It may be fascinating to explore this hypothesis.

To extend the observation along a slightly different line, about two kilograms of soil from the Pili Agriculture School were placed in each pot and lots of three pots each were given the treatment presented in table 2.[3] One tomato plant was grown in each pot. The comparative sizes of plants at harvest may be seen in figure 7.

TABLE 2.—*Average fresh weight of tomatoes given copper and zinc*

LOT NUMBER	TREATMENT	HEIGHT IN CM.	FRESH WEIGHT IN GM.
I	No treatment	21.8	16.0
II	20 cc. of 1% $ZnSO_4$ every two weeks	15.6	9.3
III	20 cc. of 1% $CuSO_4$ every two weeks	24.7	20.7
IV	2 g. NH_4SO_4 every two weeks	34.6	37.3

Fig. 7.—Comparative appearance of tomato plants at 51 days old. From left to right: I, No treatment; II, zinc sulfate; III, copper sulfate; and IV, ammonium sulfate.

Addition of copper sulfate increased the size of plants, while zinc sulfate treatment decreased growth markedly. The biggest plants were obtained with ammonium sulfate treatment; but this

[3] Mr. Virgilio F. Guevara ran the cultures.

should not be taken as an indication that nitrogen is a limiting factor in this soil. In the tomato fields of Pili, fertilization with ammonium sulfate, although promoting growth, increased the production of cupped and frizzled leaves in the later stages of development. The average of lot III (copper sulfate) could have equaled that of lot IV (ammonium sulfate) had not one of the plants lagged so far behind in growth. All these plants, regardless of treatment, were abnormally small. This may be the effect of intense sunlight and the dry atmosphere at this season of the year. A confirmatory test is being run.

The observation that copper in this soil is low is supplemented by the salutary effects of copper fertilization on plants grown in the soil. Low supply of copper is not necessarily precarious if most of it is in the readily available form. Favorable response to copper fertilization under the complex situation obtaining in the soil may indicate either a direct effect on the nutrition of the plant or an indirect effect through a change in the microbiological activity in the soil, reaction with detrimental compounds, etc.

An experiment on the effect of copper on coconut trees suffering from the cadang-cadang disease is underway.[4]

GENERAL DISCUSSION ON COPPER DEFICIENCY AND CADANG-CADANG

The approximate correlation between cadang-cadang and the light, gray-to-black soil points to a soil disturbance as a cause of the disease. The manifestation of deficiency symptoms in some plants growing in this type of soil strengthens the suspicion that cadang-cadang may in fact be just one aspect of a general reaction to a deficiency in the soil. Preliminary analysis and cultural study demonstrate an incipient deficiency of copper in the soil. Taken together, they form a strong case against the soil in the cadang-cadang question.

In the past, there was some objection to the theory that cadang-cadang is caused by a nutrient deficiency. One supposedly strong argument against it is the observation that diseased trees grow side by side with healthy trees and feed on the same volume of soil. It

[4] The following are participating in this experiment: Messrs. Processo Alcala and Juan Naron, of the Guinobatan Experiment Station, Bureau of Plant Industry; Mr. Camilo Guevara, of Pili Agricultural School; Dr. N. L. Galvez, Mr. Bonifacio Felizardo, and Mr. Virgilio F. Guevara, of the College of Agriculture, U.P.

seems that one point to be settled is whether the observed trees were intrinsically healthy or the appearance of disease symptoms was merely delayed. Whatever the case, the evidence would be equally strong in support of both the virus theory and that of nutrient deficiency.

There seems to be a slight misconception about uniformity of inception of deficiency symptoms in a group of plants. Even plants feeding in the same batch of culture solution vary greatly in growth. To quote Hewitt (1952), "Culture plants grown under apparently uniform conditions often exhibit variability in performance. This is due partly to genetic variation and partly to such factors as weight of seed and time and method of germination." Davis (1921) found that in culture solutions the mean weights of cultures vary by 20 per cent, and individual weights vary by as much as 50 per cent. If the experiments had been in sand, the variability would have been much greater. In our sand culture experiment with coconut, only the plants making up the minus-nitrogen treatment showed a fair degree of uniformity in time of exhibiting deficiency symptoms. On the other hand, a plant deprived of sulfur died in a little over one year, while one plant in this treatment has not yet shown distinct deficiency symptoms after two years. Greater variability may be expected when the deficient element is a micronutrient and still greater if the element is at incipient deficiency.

Hoagland (1944), describing the situation in a California soil which is low in zinc-supplying power, said, "In the particular peach orchard first studied, located on a sandy soil, the trees had made remarkably good growth for several years—then they became affected with the 'little-leaf' disease, as it was often called. No ordinary fertilizer treatment had any beneficial effect and plant pathologists could find no evidence that pathogenic organisms were primarily responsible for the condition of the trees. A micronutrient deficiency was early suspected but the treatment at first applied to test this possibility was not followed by any beneficial result."

Against the doubt raised by the observation that not all species of plants in the area show the copper deficiency symptoms, we may again quote Hoagland (1944): "The interest of a biologist will be attracted by the great differences among different species of plants in their ability to absorb zinc from a soil with a low zinc-supplying power. In the greenhouse, alfalfa has been observed to obtain suf-

ficient zinc from a soil in which corn plants suffer severely from lack of zinc."

Although there are some good evidences that cadang-cadang could be caused by copper deficiency in the soil, we are not proposing that they should be taken as proof. If these discussions would but stimulate thinking along this line and accelerate the activities to prove or disprove the hypothesis, we will rest content that the end has been well served.

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There are in science immense numbers of different methods, appropriate to different classes of problems; but over and above them all, there is something not easily defineable, which may be called the method of science. It was formerly customary to identify this, with the inductive method, and to associate it with the name of Bacon. But the true inductive method was not discovered by Bacon, and the true method of science is something which includes deduction as much as induction, logic and mathematics as much as botany and geology.

—*Bertrand Russell*

EFFECTS OF HERBICIDES ON WEED SPECIES IN LOWLAND AND UPLAND RICE FIELDS [1]

JULIANA N. SIERRA

WITH ONE TEXT FIGURE

Echinochloa colonum (L.) Link. was resistant to the different herbicides used in both upland and lowland rice fields. The weed was slightly injured by concentrations ranging from ¼ to 2 lbs. per acre but it recovered after one month. *Cyperus difformis* L., *Cyperus iria* L., *Fimbristylis miliacea* (L) Vahl., *Scirpus supinus* L., and *Celosia argentea* L. were killed by the chemicals at seedling stage; however, they exhibited resistance at a later stage. *Commelina benghalensis* L., an upland species, showed resistane to the spray. Broad leaves present in lowland paddies showed susceptibility to the chemicals. Pre-emergence spray was not practical. Subsequent germination of different weed species in sprayed plots showed marked increase over that of the control. Rice plants also showed signs of injury but recovered in the later stage.

The control of weeds by herbicides was better with an increase in depth of water. The weeds in the six-inch water level were comparatively less than in the two- and four-inch levels. Also, a good control was observed with the continuous flooding than in the intermittent flooding and draining. Herbicides caused a marked yellowing on both weeds and rice in the intermittent flooding and draining. The symptom is slightly manifested in the continuous flooding experiment.

Although weeds may be beneficial in checking soil erosion, supplying organic matter, and furnishing food and protection to wild life, still they comprise a major problem to farmers. Growing abundantly, they compete with cultivated plants for nutrients, water, and light and thus prevent normal growth. They also serve as hosts to many insect pests and diseases.

Most farmers control weeds by frequent cultivation, especially in upland areas. In lowland fields, weeds are often controlled by flooding the paddy soon after the seedlings are transplanted or by handweeding at intervals during the growing season. These methods are, however, inadequate, ineffective, and expensive if practiced to the extent of adequately controlling the weeds. As a supplement,

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chemicals have been widely used in many areas of the world and they may be economically practical under local conditions.

Ryker and Brown (1947) reported control of several weed species in rice fields with a 1000 ppm solution of 2,4-D applied at the rate of 1000 gallons to a hectare (37.8 liters per 100 square meters). Ryker found that rice varies in its reaction to 2,4-D when sprayed at different stages of growth; if sprayed just after germination, the plants were readily killed by the chemicals, but at later stages of growth they became less and less susceptible. Vega (1954) reported that the best time to apply the herbicide in the field was about 15 days after transplanting the rice seedlings. At this stage of growth the 30-day-old rice seedlings were less susceptible to the spray, but many weed species were still susceptible.

Sloans (1947) found that weeds similar to those found in the Philippines were killed upon treatment of 2,4-D applied at the rates of 1 and 2 pounds per acre. Tullis (1948) found the same effect of the chemical in the control of weeds in rice fields in southern Texas. Kasahara (1951) reported control of most of the common weeds in paddy field, except gramineous plants, with 2,4-D. Ocfemia and Javier (1950) found that water hyacinth, *Eichhornia azurea* Kunth, was killed by a single application of 1000 ppm aqueous solution of 2,4-D. Derico (1951) stated that a complete kill of water hyacinth in rice fields was obtained with a single application of 0.1, 0.2, 0.5, and 1.0 per cent of 2,4-D solutions. The degree of injury was proportional to the concentration used. Burgis (1951) did not completely control *Cyperus rotundus* L. with 2 and 5 pounds 2,4-D to the acre applied 3 times at monthly intervals. He attributed the appearance of new growth to the dormant tubers in the soil where the species was well established.

Harvey and Robbins (1947) reported that grasses were generally more resistant to the 2,4-D than broad-leaved species. Capinpin and Ocfemia (1948) observed that the effect of 2,4-D on susceptible broad-leaved species appeared from 6 to 12 hours after treatment. The effects were noted earlier during warm weather.

Kaufman (1954) found that rice plants were more susceptible to 2,4-D at higher temperature and at early stage of growth. He also reported that 2,4-D caused more damage to rice plants when taken through the roots than through the leaves. Ingebretsen (1954) found that spraying 55 days after transplanting gave excellent control of sedge and cattail. Considerable regrowth occurred in the

early sprayed area, but in area sprayed at 65 days some of the weeds were mature enough to withstand the herbicidal effect. He also reported that MCP was safer than 2,4-D. Davis (1954) reported that harmful weeds are retarded in growth as the depth of water increases. As long as the depth is not increased to a point detrimental to the growth of rice, irrigation becomes an effective weed control practice. Seeding of rice, followed by immediate submergence of the land, gives the rice a favorable advantage over weeds.

Weaver, Minarik and Boyd (1946) reported that rain within 24 hours after application of the herbicides reduced the effectiveness of the spray. Dew on the leaves of the plants diluted the spray, and winds increased hazard from drift. Mitchell (1947) stated that 2,4-D penetrates into the plant easily and once inside moves upward and downward.

This study was initiated to study the effects of herbicides on different species of weeds found in upland and lowland rice fields and to determine the chemicals and concentration most effective in controlling them. The experiments were conducted in the Department of Agricultural Botany and in the Central Experiment Station from December, 1954, to January, 1956.

MATERIALS AND METHODS

The herbicides used in the study were:

1. 2,4-D amine—triethanolamine formulation of 2,4-dichlorphenoxy-acetic acid
2. 2,4-D ester (LV-4)—propylene glycol butyl ether ester of 2, 4-dichlorphenoxyacetic acid
3. 2,4,5-T-2,4,5-Trichlorphenoxyacetic acid
4. CMU—3 para chlorophenyl 1, 1-dimethyl urea
5. MCP—Amine salt of 2 methyl 4-chlorophenoxy-acetic acid
6. Kuron—2,4,5-trichlorophenoxypropionic acid
7. Dow Premerge—amine salt of dinitro orthro-secondary butyl phenol
8. Dalapon—Sodium salt of 2-2-dichloropropionic acid 78% active ingredient
9. Amino triazole—3-amino-1,2 4-triazole

Germination studies. To determine percentage germination and length of dormancy of some weed species, some seeds were collected and air-dried for 2 weeks.

Experiment IA. Germination in pots. Pots 30 centimeters in diameter and 35 centimeters in height were filled with clay loam

soil which had been well pulverized, sieved, and mixed thoroughly. Ten pots were planted to each of the four species: *Echinochloa colonum, Cyperus difformis, Digitaria sanguinalis* and *Eleusine indica* (L.) Gaertn. An average of 50 seeds of each species was planted approximately two centimeters deep in each pot. All pots received equal amounts of water, applied uniformly over the soil surface. Observations were noted and height measurements taken at weekly intervals.

Experiment IB. Germination in Petri dishes. The germination of *Echinochloa colonum* and *Cyperus difformis* was further studied in Petri dishes. The dishes were fitted with filter paper and sterilized in an autoclave at 20 pounds pressure for 30 minutes. After the dishes had been cooled, 50 seeds of each species were arranged in each of them with more or less equal spacing between seeds.

Twelve Petri dishes of each species were prepared; 6 of these were placed in diffused light, and the other 6 were left in direct sunlight. Water was added whenever necessary to keep the filter paper moist.

Percentage germination was determined, and measurements of the hypocotyl and epicotyl of the germinating seeds were taken 7 days after emergence.

Experiment II. Pre- and post-emergence treatments on weed species in upland rice field. An area of land in the upland portion of the Central Experiment Station was used for a study of the reaction to herbicides of weeds at different stages of growth. It was set up in a randomized block design with six replications. The entire area for both pre- and post-emergence plots was planted with the conventional grain drill on June 13, 1955. The following day it was staked into 2 × 8-meter plots which were 3 feet apart to facilitate spraying.

The treatments applied were as follows:

CHEMICALS	CONCENTRATION	
	Pre-emergence	Post-emergence
2,4-D Amine	1 and 2 lbs.	¼, ½ and ¾ lb.
2,4-D Ester	1 and 2 lbs.	¼, ½ and ¾ lb.
2,4,5-T Ester	1 and 2 lbs.	¼, ½ and ¾ lb.
MCP	———	¼, ½ and ¾ lb.
Kuron	———	¼, ½ and ¾ lb.
Dow Premerge	6 and 9 lbs.	———
CMU	¾ and 1½ lbs.	———
Handweeded	3 times	3 times
Control	No treatment	No treatment

Twelve plots in each of 6 rows were used for pre-emergence treatments; the rest (306) for post-emergence treatments. The pre-emergence treatments were applied 3 days after planting. Observations were made and the effect of the pre-emergence treatments on the different weed species were recorded. With a 25 × 25-centimeter quadrat, weed counts were made at two locations in each plot 23 days after spraying. The post-emergence treatments were applied on the following dates and at the growth stage indicated:

1. June 30, 1955	Weeds in seedling stage (18 days after planting)
2. July 11, 1955	Weeds in vegetative stage (29 days after planting)
3. July 19, 1955	Weeds in early flower bud stage (37 days after planting)

All treatments were applied using a knapsack sprayer equipped with a two-meter boom and operated at 40 pounds per square inch pressure and at 2 miles per hour.

A second experiment on pre-emergence treatments was started on July 23, 1955. One-half of the area used in the first pre-emergence experiment was plowed and staked into rows. The same experimental design as in the first experiment was followed, and the same chemicals and concentrations were used. Weed counts were made 15 days after treatments.

Experiment III. Follow-up experiment in upland field. To study further the effect of herbicides on different weed species, a portion of an upland field infested with weeds was selected. The field was plowed and fitted but no crop was planted. On June 4, 1955, 3 × 10-meter plots were staked out and sprayed. The chemicals used were 2,4-D amine, 2,4-D ester, 2,4,5-T ester, and 2,4-D plus 2,4,5-T at rates of ¼, ½, and ¾ pound per acre. Weed species present were *Echinochloa colonum, Malvastrum coromandelinum* (L.) Garcke, *Ipomoea triloba* L., *Crotolaria incana* L., and *Mimosa pudica* L. Before spraying, the heights of both the broad-leaved and grass species were taken at random.

Treatments were applied with the knapsack sprayer used in the preceding experiment. Treatments were applied at the rate of 15 gallons herbicide solution per acre.

Observations on the different species were made and weed counts were taken with a 25 × 25-centimeter quadrat at 4, 10, and 30 days after treatment.

To determine susceptibility at different growth stages a second series of plots were sprayed one week later with the same chemicals and concentrations. Observations were taken and weed counts were made at the same intervals.

Experiment IV. Pre-emergence control of weeds in lowland rice field. A block of 30 paddies, each measuring 2½ × 12 meters was plowed, harrowed, and levelled. Four different chemicals at two concentrations were systematically randomized with three replications of each treatment. A check plot was located between each replicate. The chemicals used were Dalapon at 20 and 40 pounds, 2,4-D amine, and amino triazole at 4 and 8 pounds, and CMU at 2 pounds per acre.

The knapsack sprayer with a two-meter boom was operated at the same pressure and mileage. All treatments were applied in 30 gallons of water. Twenty-seven days after treatments, weed counts were made with a 25 × 25-centimeter quadrat.

Experiment V. Post-emergence control of weeds in lowland rice field. Four blocks each with thirty 2 × 12½ meter individual paddies, were planted on July 18, 1955, with 11-day-old dapog seedlings of Thailand rice variety. The seedlings were transplanted 20 centimeters between hills in rows 30 centimeters apart with 4 to 6 seedlings per hill. The experimental design was a randomized block with four replications of each treatment.

The chemicals used were 2,4-D amine, 2,4-D plus 2,4-5-T (a mixture of 2,4-D and 2,4,5-T containing 2 pounds per gallon of each chemical), 2,4,5-T ester, MCP, LV-4, and Kuron. Aqueous solutions of the chemicals were applied at ¾ and 1½ pounds per acre on August 13 (27 days after transplanting) and September 1 (40 days). All plots received only one treatment.

The plots were drained two days before treatment and water was restored three days after treatment. Then they were intermittently flooded and drained.

Weed counting with a 25 × 25-centimeter quadrat was made 30 and 60 days after treatment. The quadrat was placed at four different locations in each plot and the number of individual species inclosed was counted.

Experiment VI. Treatments on weed species in lowland rice field under continuous flooding. Ten treatments of four replications and 2, 4, and 6-inch water levels were used. On August 9, 1955, nine-day-old seedlings of Milfor rice variety were transplanted to each 2½ × 8-meter paddy. The seedlings were transplanted approximately 30 centimeters apart in rows and 20 centimeters between hills with 4 to 6 seedlings per hill.

The sprays used were 2,4-D amine, LV-4, MCP amine, and Kuron at concentrations of one and two pounds per acre.

Weed counts with a 25 × 25-centimeter quadrat were made 20, 40, and 60 days after treatment.

Experiment VII. Treatments on weed species in lowland rice field under intermittent flooding and draining. Rice seeds of Milfor variety were planted in a dapog bed. After nine days the seedlings were transferred to the ordinary wet bed. They were transplanted to 2½ × 8-meter paddies on August 31, 1955. Four blocks of 30 paddies each were used. The chemicals were the same as those used in continuous flooding, but the concentrations were ¾ and 1½ pounds per acre. In flooding three levels of water (2, 4 and 6 inches) were maintained. Each treatment was replicated four times. The plots were drained two days before treatment and water was restored three days after treatment. Then intermittent flooding was continued.

Data on the effects of herbicides on the rice plants and weeds were noted. Weed counts were made 20, 40, and 60 days after treatment.

In all the experiments, the herbicides were applied at 15 gallons per acre, the dilution of which was based on active ingredient of formulated materials available.

RESULTS AND DISCUSSION

Germination studies. Experiment IA. Of the weed species planted, only 3 germinated, namely, *Echinochloa colonum, Digitaria sanguinalis,* and *Eleusine indica.* Emergence from soil was noticed in four days and continued up to 20 days after planting.

Figure 1 shows weekly height measurement averages of *Echinochloa colonum, Eleusine indica* and *Digitaria sanguinalis.* Data obtained showed that the most rapid increase in height was obtained in the fifth and sixth weeks.

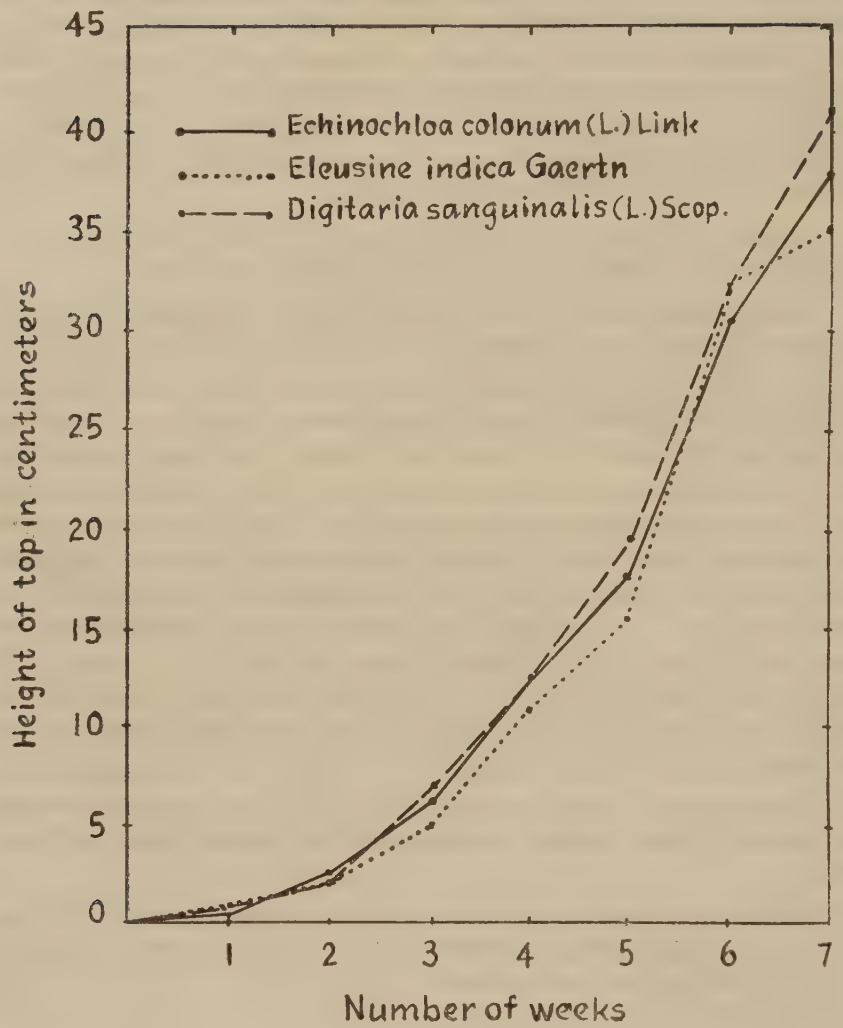

Fig. 1.—Average height of the three species of weeds at weekly intervals.

Eleusine indica started flowering 33 days after planting. Other species flowered later. In six weeks all species had flowered and at the end of the seventh week they were all in full bloom.

Experiment IB. No germination was obtained in either *Echinochloa colonum* or *Cyperus difformis* placed in diffused light.

In those exposed to direct sunlight, germination ranged from 26 to 60 per cent. *Cyperus difformis* failed to germinate in direct

sunlight. Roots of one-week-old seedlings of *Echinochloa colonum* tended to be longer than shoots. Replication 3 with 50 per cent germination produced the longest root and shoot. With an increase in length of root there was a corresponding increase in length of the shoot.

Experiment II. Effect of pre- and post-emergence treatments on weeds in upland rice field. A. Pre-emergence treatments. Few weeds are present in the treated area as compared to the control (table 1). The areas treated with CMU at 1½ pounds per acre and Dow Premerge at 9 pounds per acre gave excellent control.

Of the broad-leaved weeds, *Amaranthus spinosus* L. was the most susceptible with a control of 83 to 100 per cent. This was followed by *Celosia argentea, Ipomea triloba, Mimosa pudica, Portulaca oleracea* L., and *Commelina benghalensis*. The stand counts on *Commelina benghalensis* sprayed with the translocated herbicides showed an increase in number over that of the unsprayed. On *Commelina benghalensis* the 6-pound per acre concentration of Dow Premerge, however, effected a 57 per cent control and the 9 pounds per acre, 75 per cent. The results from Dow Premerge were more evident when the stand count was made, because it is a contact-type herbicide and susceptible weeds are killed within two to three days after spraying.

In the grass family, *Digitaria sanguinalis* was the most susceptible, the percentage control ranging from 75 to 100, except in 6-pound per acre Dow Premerge and in 2-pound per acre 2,4,5-D amine. Cyperus was also controlled except in the lower concentrations of 2,4-5-T ester and CMU.

Although good control of the different weed species was obtained in some treatments, the stand of rice was markedly reduced. Treatments with 2,4-D ester, Dow Premerge and CMU resulted in poor stand of rice plants, chlorosis, and thin and rolled leaves.

The handweeded plots had a lower number of weed species present. The stand count showed a total number of 101 compared to 151 in the control. The weed species in the control plots were vigorous. Rice plants with spreading dark green leaves were also vigorous. The weeds on the handweeded plots were all seedlings or regrowth from those that had broken off during weeding.

In all chemicals, the higher concentrations were more effective. Except for the *Echinochloa colonum* in 2,4-D ester at the rates of one and two pounds per acre, *Eleusine indica* in 2,4,5-T, and *Calo-*

TABLE 1.—*Effects of different herbicides applied as pre-emergence treatment on weed species in upland rice field* [a]
Average number per sq.m.

SPECIES	CHEMICALS USED										HAND-WEEDED	CONTROL
	2,4-D amine		2,4-D Ester		2,4,5-T Ester		Dow Premerge		C.M.U.			
	1 lb/acre	2 lb/acre	1 lb/acre	2 lb/acre	1 lb/acre	2 lb/acre	6 lb/acre	9 lb/acre	¾ lb/acre	1½ lb/acre		
1. *Cyperus rotundus* L.	12 [c]	4	7	7	12	11	27	5	33	17	5	17
2. *Echinochloa colonum* (L) Link.	23	7	4	36	29	12	28	13	17	12	25	12
3. *Eleusine indica* (L) Gaertn.	9	—	12	2	9	17	4	16	5	1	15	29
4. *Digitaria sanguinalis* (L) Scop.	—	8	1	—	1	—	8	1	1	—	—	4
5. *Amaranthus spinosus* L.	5	1	7	1	—	7	4	4	—	—	4	43
6. *Celosia argentea* L.	1	3	3	5	—	3	4	1	4	—	4	7
7. *Commelina benghalensis* L.	25	16	33	37	28	12	5	3	45	27	28	12
8. *Portuloca oleracea* L.	1	1	1		1	—	—	5	1	—	4	3
9. *Calopogonium muconoides* Desv.	9	13	20	31	17	13	15	13	11	13	16	16
10. *Ipomoea triloba* L.	1	1	1		1	—	1	1	—	—	—	4
11. *Mimosa pudica* L.	1	—	—	1	—	—	—	—	—	—	—	4
Total	87	54	89	121	98	75	96	62	117	70	101	151

[a] Sprayed—June 16, 1955.
[b] Average of six replications.
[c] Counted—July 9, 1955.

pogonium muconoides Desv. in 2,4-D amine, there was an increase in number of weeds. This variation in number is due to seedling weeds which were present at the time of spraying and those which germinated after. The interval between spraying and counting was too short to determine the actual effect of the herbicides. This variation may also be attributed to uneven distribution of species in the area treated or to the stage of germination when the chemical was applied.

In plots treated on July 23, 1955, in the same area, similar observations were noted. The 2,4-D amine at two pounds per acre, 2,4,5-T ester at one and two pounds per acre, and 2,4-D ester at one and two pounds per acre effected a better control of *Amaranthus spinosus* than Dow Premerge (table 2). The control in the different chemicals ranged from 6 to 100 per cent.

In the plots treated with 2 pounds per acre of 2,4-D ester and 2,4,5-T ester, germination of both rice and weeds was very poor. The effect on the broad-leaved species was similar to that in the first experiment.

B. Post-emergence treatments. Spraying the field after emergence of the plants showed a more pronounced effect.

At seedling stage. Rice plants sprayed at seedling stage turned yellow and chlorotic. The ¾-pound per acre concentration of the different chemicals resulted in marked stunting of the plants. With lower concentrations the plants recovered in 30 days.

Echinochloa colonum exhibited symptoms similar to the rice plants; however, yellowing was only temporary and recovery rate was faster.

Of the broad-leaved weeds, *Celosia argentea* was the first to show signs of injury. The effects noted were bending of the leaves and twisting of the stem. *Commelina benghalensis, Calopogonium muconoides, Portulaca oleracea, Ipomoea triloba,* and *Euphorbia hirta* were also susceptible to the spray. *Commelina benghalensis* produced nodule-like outgrowth in the stem, and its growth was stunted. Good control of *Celosia argentea* (100 per cent) and *Amaranthus spinosus* (57 per cent) was obtained with 2,4-D ester at ¾ pound per acre.

Higher concentrations had a greater effect on the number of weeds present except in the Kuron treatment. However, the final results based on later observations did not show this difference.

TABLE 2.—*Effects of different herbicides on weed species in an uncropped upland field* [a]
Average number per sq.m.

SPECIES	COUNTINGS MADE	CHEMICALS AND RATES USED												CONTROL
		2-4-D amine			2,4-Ester			2,4,5-T Ester			2,4-D plus 2,4,5-T			
		¼	½	¾	¼	½	¾	¼	½	¾	¼	½	¾	
		lbs./acre			lbs./acre			lbs./acre			lbs./acre			
1. *Echinochloa colonum* (L) Link	First [b]	262	166	54	154	58	32	221	42	10	205	32	29	45
	Second [c]	205	192	32	86	90	26	182	54	22	227	67	45	13
	Third [d]	90	70	16	109	54	13	179	16	51	38	54	26	29
2. *Malvastrum coromandelinum* (L) Garcke	First	202	262	314	208	320	384	253	237	262	272	304	326	506
	Second	106	74	148	106	141	179	67	67	54	83	131	67	506
	Third	42	45	134	13	38	22	45	86	38	22	10	41	493
3. *Crotolaria insana* L.	First	3			13		32							13
	Second	6		42	13									29
	Third				6				13					45
4. *Ipomoea triloba* L.	First					6	3		3			16	4	6
	Second				7									13
	Third				3									6
5. *Mimosa pudica* L.	First	35	13		67	3		48	3		19			16
	Second							16			13			29
	Third							51			3	3		35
Total	First	502	441	368	442	387	451	522	298	272	496	352	359	586
	Second	317	266	222	208	231	205	265	121	76	323	198	112	590
	Third	132	115	150	131	92	35	293	115	89	63	67	67	608

[a] Sprayed—June 4, 1955.
[b] First counting, June 7, 1955.
[c] Second counting, June 16, 1955.
[d] Third counting, July 16, 1955.

The higher concentrations resulted in a quicker initial effect, but the actual control by the lower concentrations in the broad-leaved species was just as good. The best control was obtained in 2,4-D amine and 2,4,5-T ester at ¾ pound per acre. The effect of 2,4-D ester was more rapid than that of the amine and the percentage kill was higher, although these differences are not shown by the stand count.

Weeds at vegetative stage (about 10 to 20 centimeters tall). Rice plants showed less injury from the chemical sprayed. There was no evidence of yellowing and only slight malformation was noticed.

The weed species present, especially the broad leaves, were quite susceptible to the sprays. A good control of *Calopogonium muconoides* was obtained, the percentage kill based on stand count ranging from 45 to 100 per cent. *Amaranthus spinosus* decreased as concentration increased. A good control of *Portulaca oleracea* was also obtained. The 2,4,5-T ester resulted in better control of *Celosia argentea* than any other chemical. Based on stand counts, *Digitaria sanguinalis* was the most susceptible of the grass species, the control being 50 to 100 per cent. Less number of *Eleusine indica* was present in higher concentrations, except in the MCP treatment. Based on observation in other experiments, reduction in number of *Echinochloa colonum* was also noted, especially in Kuron at ¾ pound per acre. This difference in occurrence is probably due to variations in stand, not to the effectiveness of Kuron on Echinochloa.

The 2,4-D amine at ¾ pound per acre gave the most promising control. In the handweeded plot the total of 62 was comparatively less than the 103 of the control.

Weeds at early flower bud stage. Signs of injury in the weeds and rice plants sprayed were noted comparatively later than in those sprayed at earlier stages. A slight yellowing was observed in both the rice and the grass sprayed with higher concentrations. Grasses were dark green and vigorous; they were as tall as the rice plants. The most noticeable effect was the spreading of the branches and an increase in the red pigment, particularly at the base.

A good control of the broad-leaved species was obtained. Drying of the plants was noticed after 10 days. There was a more or less uniform percentage of control of the *Amaranthus spinosus* and

Celosia argentea. Percentage kill of *Cyperus rotundus* ranged from 27 to 100 per cent; and of *Commelina benghalensis,* 70 to 100 per cent.

Echinochloa colonum was quite resistant to the spray. There was a greater number in the treated plot than in the control, except in the ¼ and ¾ pound per acre applications of 2,4,5-T ester. This observation may have been due to differences in the weed population in the given areas. Since only one stand count was made in these experiments, the numbers do not reflect a true picture of the actual results. The control on *Calopogonium muconoides* which had germinated was 100 per cent, but due to frequent rains the residual effect of the chemical was apparently very short. The weed seeds which germinated 10 days or more after spraying were not controlled. *Calopogonium muconoides* germinated over a longer period than any other species.

In the handweeded plots the number of species at early flower bud stage was less than in the control plots; however, seedling weeds of all the species were present. Based on the total weed population, the control in the handweeded plots was 54 per cent.

In the control plots, both the broad-leaved and grass species were about 1½ to 2 feet in height so that at times rice plants could not be seen.

The percentage control of any species in upland areas was greatly influenced by the amount and time of rainfall. The shorter the interval between spraying and rainfall, the lower the percentage kill. To obtain a satisfactory kill of susceptible species an interval of 4 to 6 hours was needed.

In view of the frequent rains which normally occur during May and June, pre-emergence treatment with the chemicals used is a questionable practice. A highly insoluble form of chemical not subject to leaching might be effective. Post-emergence treatments, provided not washed off the leaves by rain shortly after treatment, would be safer.

The control of members of the grass family at early bud stage is a serious problem; hence, the use of post-emergence treatments would necessitate handweeding or cultivation to remove the grasses. If pre-emergence treatment could be used without danger of damaging the germination of the rice, the grass problem could be reduced in the seedling stage.

Experiment III. Follow-up experiment in upland field. Prevalent weed species sprayed on June 4, 1955, were *Malvastrum coromandelinum, Echinochloa colonum, Crotolaria incana, Ipomea triloba,* and *Mimosa pudica.* At the time of spraying the broad-leaved species were 1.5 to 4.5 centimeters in height and the grass, 4 to 7 centimeters.

The first noticeable effect was slight epinasty of the leaves 6 hours after treatment. After 24 hours the broad-leaved species exhibited definite wilting. The leaves bent at the petioles and dropped to the sides and the stem became brittle and twisted. Wilting began from the youngest leaf and from the margin. After 6 to 10 days the leaves and the stem turned brown and began to dry up. Nodule-like outgrowth on the stem near the roots in *Malvastrum coromandelinum* was formed. Ten days after spraying, all the plants seemed to be dead, but 30 days after, regrowth took place. Plants that were regrowing were thin and not as vigorous as the control.

Mimosa pudica had yellow leaves 2 days after spraying, and was completely defoliated later. After 20 days, a new set of leaves was produced and the plants appeared normal.

The first effect observed on the grasses was slight yellowing of the leaves which lasted for a short time. The grasses recovered and growth was as vigorous as if they had not been treated.

Echinochloa colonum sprayed with ¼ pound per acre of 2,4-D ester showed a decrease in the second counting but an increase in the third. This may have been due to good control of the broad leaves and thus less competition for space. The grass, being resistant to the spray, may have taken over the area.

A given species which did not appear in the first count but showed up in the second or third may not have germinated at the time of spraying, and the residual effect of chemicals may not have been sufficient to control them at germination.

The effect noted in the second experiment was the same as in the first, except that the first signs of injury appeared later. The higher concentrations of chemicals resulted in a more effective control.

Grasses were less in the second experiment than in the first but it can not be concluded that they are susceptible, because there was a fewer number of grass species in the area at the time of treatment.

Experiment IV. Effect of pre-planting treatment on weed control in lowland rice field. Data obtained showed that pre-planting treatment in lowland rice is not practical; instead of reducing the number of weed species in the treated area, it caused an increase in weeds, except in the CMU treatment which gave a 70 per cent control.

A good control of *Sphenoclea zeylanica* Gaertn. was obtained in the different treatments, except in the lower concentrations where there was an increase over the control. *Fimbristylis miliacea,* except in the CMU treatment, showed a marked increase in number compared to the control.

The problems associated with pre-planting treatment include: (1) the weed species present, (2) the length of time required for the chemical to be decomposed or leached to a level that would not affect germination of rice, (3) the need for additional seed-bed preparation which would bring new weed seeds to the surface, and (4) the cost of application.

Experiment V. Effects on weeds and on rice in lowland rice field applied at two different dates.

On weeds. A more pronounced effect was observed in plants sprayed 27 days after transplanting than in those sprayed 40 days (table 3). This may have been due to differences in susceptibility of the weed species at the different growth stages.

Members of the family Cyperaceae and broad-leaved species seemed to be more susceptible to the chemicals sprayed. Table 3 shows the number of weed species present in the treated area.

From the first to the second count, a reduction of the number of weeds was obtained in all treatments. Even though grasses are considered resistant to 2,4-D and related compounds, the results of this experiment showed that if chemicals are sprayed when grasses are in seedling stage the number is reduced and those that survive are stunted in growth.

Recovery of the different species was observed only at the lower concentrations. *Cyperus iria* and *Echinochloa colonum* recovered from 2,4-D amine treatment at ¾ pound per acre, and *Fimbristylis miliacea* from 2,4,5-T ester treatment at the same rate.

In plots treated 40 days after transplanting, a decrease in the weed population was also obtained. As in the 27-day treatment, species belonging to family Cyperaceae and broad leaves were suscep-

TABLE 3.—*Effects of ¾ pound per acre of different herbicides on weed species in lowland rice field*
Average number per sq.m. [a]

SPECIES	COUNTINGS MADE	CHEMICALS USED														CONTROL	
		2,4-D amine		2,4-plus 2,4,5-T		2,4,5-T Ester		M.C.P. amine		LV-4 Ester		Kuron		Hand-weeded			
		27 [b]	40 [c]	27	40	27	40	27	40	27	40	27	40	27	40	27	40
1. *Cyperus difformis* L	First [d]																
	Second [e]			2	2				2	1			2			5	10
2. *Cyperus iria* L.	First	8		16	3	5	1	4	6	4	1	11	2		10	14	24
	Second	9	1	4	1	10		4	4	2		8	20	11	1	12	16
3. *Fimbristylis miliacea* (L) Vahl.	First	21	2	6		19		6	16	9		32		18		53	16
	Second	9	1	2		24		5	4	5		27		9	6	43	20
4. *Scirpus supinus* L.	First	1						5					2			2	
	Second							1					2	9		2	20
5. *Echinochloa colonum* (L) Link.	First	36	36	45	37	37	37	47	44	58	36	58	27	43	5	43	21
	Second	40	28	28	29	39	20	42	38	52	27	39	29	26	8	41	15
6. *Paspalum conjugatum* Berg.	First					1											
	Second																
7. *Jussiaea suffruticosa* (L)	First					21						7		9		20	3
	Second											7				11	20
8. *Sphenoclea zeylanica* Gaertn.	First	8		1		2		6		9		26		21	1	36	4
	Second												24		2	4	10
Total	First	74	38	68	42	85	38	68	66	80	37	134	31	91	16	138	68
	Second	58	30	36	32	73	20	52	48	55	27	105	53	55	17	118	111

[a] Average of four replications.
[b] Sprayed 27 days after transplanting
[c] Sprayed 40 days after transplanting.
[d] Counted 30 days after spraying.
[e] Counted 60 days after spraying.

tible, but grasses were resistant, although reduction from the first to the second count was also observed. Recovery of the *Echinochloa colonum* was observed only in Kuron treatment at 1½ pounds per acre.

On rice. The nature of the effect on rice using related compounds of 2,4-D was more or less the same, the only variation being in the degree of injury, which was affected by concentrations. The injuries noted were temporary wilting of the leaves, spreading of tillers, stunting of growth and abnormal development of roots. There is an increase in the number of roots which are short and stout and usually arising from the portion slightly above the ground.

Experiment VI. Effects on weeds in lowland rice field under continuous flooding. Weeds of the family Cyperaceae reacted differently to different water depths. *Cyperus difformis* and *Cyperus iria* decreased in number as depth of water increased. *Fimbristylis miliacea* increases, especially in the MCP and Kuron treatments; however, a good control was obtained in 2,4-D and LV-4 treatments.

The broad-leaved species were susceptible to the spray. As depth of water was increased, their number decreased. *Sphenoclea zeylanica* exhibited brittle and twisted stem three days after spraying and soon dried up; however, new seedlings appeared afterwards.

Echinochloa colonum was not seriously injured by the spray; neither was it affected much by the different depths of water. The number in the two-and four-inch water depths was more or less the same; a slight decrease in number in the six-inch water depth was noted.

There were less weeds in the handweeded plots than in the unsprayed or control plot. The handweeded plots were fairly clean, free from mature weeds, but with plenty of small germinating weeds. In the unsprayed plots, weeds particularly *Echinochloa colonum* were about ¾ the height of the rice plants. Their growth was thick and vigorous, and at the time of counting they were already flowering.

There was a marked decrease in the number of species in the treated area as compared to the control. There were cases wherein the second count (40 days after spraying) was less than the first (20 days) and then less than the third (60 days). This may have been due to the incomplete effect of the chemical at the first counting.

The rice plants exhibited slight yellowing of the leaves, followed by curling of the leaves and drooping of the stem. Yellowing of the plants was evident for a short time. After one month, the plants turned dark green; they retained this color throughout the growing period.

Experiment VII. Effect on weeds in lowland rice field under intermittent flooding and draining. In the treated plots there was a decrease in weed population. The broad-leaved species were susceptible to the spray but grasses were resistant. The predominant weed species left was *Echinochloa colonum.* In plots subjected to a water depth of two inches, the control of *Echinochloa colonum* by the different chemicals ranged from 0 to 34 per cent. In 2,4-D amine treatment, the number was even greater than the control and recovery was observed in the second counting. The percentage control in the four-inch depth was 0 to 40, and in the six-inch, 0 to 50.

Sphenoclea zeylanica also showed resistance to the depth of water used. Alternate flooding and draining of the field favored weed germination. Draining may have favorably affected germination, and flooding may not have affected it seriously.

The effect on the rice plants was severe. Marked yellowing of the leaves, curling of the tips, and stunting of growth were observed.

Regardless of depth, continuous flooding was much superior to intermittent flooding as a weed control practice. The interval used in intermittent flooding was long enough to allow germination while the water was off, and the five days of flooding was not long enough to control even the susceptible species.

In these experiments, continuous flooding was an effective weed control practice. The combination of the use of herbicides and continuous flooding appeared to be even more advantageous. Handweeding or cultivation was apparently necessary to prevent regrowth of the weeds.

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* * *

Many expositions of science have laid so much stress on science and so little on scientists that the layman thinks of science as a mechanical system which can be operated by anyone who has learned the routine and which will give equally satisfactory results regardless of the operator.

—*Allen Gregg*

FB-24, A "RUNNER" TYPE VARIETY OF RICE

FB-24, a medium-lodging lowland rice variety which is about 170 cm. in height at maturity (152 days from sowing in seedbed) was found to produce vigorous shoots at the nodes of stalks left after the panicles of the main crop were harvested. This was observed in the 1956 wet season test at the Central Experiment Station, College, Laguna.

In harvesting the experimental plots, the rice stalks were cut about 3 cm. from the ground to encourage production of tillers at the base of the plants. In the extra plots, the panicles were cut above the last node. Where the plants were not cut close to the ground, FB-24 exhibited its "runner" habit. The shoots at the nodes burst out six days after the main crop had been harvested. In the experimental plots, the base tillers started to come out three days after harvesting, or three days earlier than the "runner" shoots. In the extra plots, nodes that came in contact with the soil rooted, and after the old stalk decayed, the shoots from these nodes established themselves as new and independent plants. Shoots from the reclining stalks that did not come in contact with the soil also continued to grow. These "runner" shoots grew more uniformly than those from nodes that rooted.

In general, each node of the rice stalk produced a shoot. The number of "runner" shoots produced from one rice stalk varied from three to six (fig. 1). Some culms did not produce any "runner" shoot at all. On the average, each culm had three "runner" shoots.

The "runner" shoots and the base tillers started to head at about the same time although the base tillers emerged three days earlier than the "runner" shoots (fig. 2). These base tillers had uneven heading. Some panicles from the base tillers were just emerging from the boot while the others were already well exserted from the flag leaf. Heading of the "runner" shoots was considerably uniform. The number of days from harvesting of the main crop to heading of the "runner" shoots and most of the base tillers varied from 41 to 45 days. The first ratoon crop was harvested 28 days after heading.

Fig. 1.—"Runner" shoots of a stalk of FB-24 already heading.

Fig. 2.—A hill of FB-24. Note the even heading of the "runner" shoots and the relatively uneven heading of the base tillers.

In one ratoon plot, the computed yield of FB-24 was 25 cavans (at 14 per cent moisture) per hectare and that from the "runner" shoots was 28 cavans per hectare.

Of hybrid origin, FB-24 variety was produced by Mr. Esteban Cada, Plant Breeder of the Maligaya Rice Experiment Station in Nueva Ecija.

—J. N. Tepora and D. L. Umali

* * *

History celebrates the battlefields whereon we meet our death, but scorns to speak of the plowed fields whereby we live; it knows the names of the kings' bastards, but cannot tell us the origin of wheat. This is the way of human folly.

—Henri Fabre

* * *

The whole of science is nothing more than a refinement of everyday thinking.

—Einstein

* * *

Research is worthy of the name only as it is directed to the answering of definite problems by scientific methods of procedure. It presupposes a definite aim and a definite problem to be solved, a definite end to be attained rather than the mere accumulation of data.

—True

DR. GERARDO O. OCFEMIA, PROFESSOR OF PLANT PATHOLOGY, RETIRES AFTER 42 YEARS OF SERVICE

On April 10, 1957, Dr. Gerardo O. Ocfemia ended a remarkable 42-year record of service to the College of Agriculture, University of the Philippines. He retired one year beyond the automatic and compulsory retirement age having been granted an extension of one school year by the late President of the Philippines, Ramon Magsaysay.

Dr. Ocfemia served the College of Agriculture in various capacities. He was Assistant Instructor in Agronomy from 1915 to 1917; Assistant Instructor in Plant Physiology from 1917 to 1918; Assistant Instructor in Plant Pathology from 1918 to 1920; Instructor in Plant Pathology in 1920; Assistant Professor of Plant Pathology from 1924 to 1932; Associate Professor of Plant Pathology from 1932 to 1945; and Professor of Plant Pathology from 1945 to 1957. He was acting head of the Department of Plant Pathology from 1928 to 1933. In 1933, he was appointed head, a position he held up to 1955.

The eminent plant pathologist was born to Rufo and Juana (Offimaria) Ocfemia on April 23, 1891, in Guinobatan, Albay. He was one of the earlier products of the College of Agriculture, graduating in 1915 with a B.Agr. degree and in 1920 with an M.S. degree. He obtained his Ph.D. degree in 1923 from the University of Wisconsin. On his return to the Philippines, he married Miss Epifania San Valentin in Los Baños, Laguna, on October 1, 1923. Five children were born to them: Rufo Honorio, Norma, Wenefrida, Fe, and Epifania Caridad.

The outstanding contributions of Dr. Ocfemia lie in the field of virus diseases of plants, specifically the bunchy-top of abacá, or Manila hemp plant, Fiji disease of sugar cane, and certain phases of the mosaic of sugar cane, throwing light on the nature, cause, and method of transmission of the first two diseases. His findings on the mosaic of abacá have provided the basis for the government's large-scale abacá mosaic control program in Mindanao. His article cn "Experimental transmission of aspermy virus to the Philippine

Canna indica" published in *The Philippine Agriculturist* **40**: 4-6, 1956, and which will be reprinted in the "Studies from the Rockefeller Institute" received commendation from Dr. F. O. Holmes, a well-known authority on virus diseases of plants. His published works include 53 scientific and 34 popular and semipopular papers. Fifty-five scientific articles were also prepared under his direction.

His last acts in the College consisted of consolidating data for the revision of "Philippine Agriculture, Volume I, 'Field Crops'," and writing the manuscript of "Electron microscopy of unpurified extracts of coconut infected with cadang-cadang disease."

Dr. Ocfemia is a member of various scientific and honorary organizations. He is a fellow of the A.A.A.S.; member of American Phytopathological Society; Botanical Society of America; Sigma Xi, Phi Kappa Phi; Charter member, Society for the Advancement of Research; Charter member, National Research Council of the Philippines of which he is Chairman, Section of Plant Pathology and Mycology; member of the Los Baños Biological Club; and active member of the New York Academy of Sciences.

Dr. Ocfemia was a U.P. fellow at the University of Wisconsin, 1920-1923 and a fellow of the John Simon Guggenheim Memorial Foundation and concurrently Visiting Investigator in the Rockefeller Institute for Medical Research, New York, 1955. He was member of the Committee of Cane Diseases, 6th International Society of Sugar Cane Technologists, Baton Rouge, La., 1938; delegate to the 6th Pacific Science Congress, San Francisco, Berkeley and Stanford University, 1939; and member of the Standing Committee on Nomenclature of Sugar Cane Diseases of the World, International Society of Sugar Cane Technologists, 1951 to date.

He is contributor to *Phytopathology* and the *American Journal of Botany*. He was Managing Editor of *The Philippine Agriculturist* from 1938-1941 and from 1947-1955.

Together with two other faculty members of the College of Agriculture, Dr. Ocfemia was named among the ten outstanding scientists for 1955.

With his retirement, the College lost a scientist, well known in his chosen line. In gratitude, the staff of the Department of Plant Pathology hopes to carry on, guided by his silent but consistently devoted love for research.

—*Victoria M. Ela*

ERRATA

In volume XLI, Nos. 1 & 2, June-July, 1957 number of *The Philippine Agriculturist* page 8, line 16, the sentence "Guimbalaon showed 62 to 71 per cent in the volume decreasing to 35 per cent below 50 inches." should read "Guimbalaon showed 62 to 71 per cent clay in the upper 40 inches and 35 per cent below 50 inches." In line 22 "phosphorus ferro-allophane-like minerals" should read "amorphous ferro-allophane-like minerals." On page 10 "silien" should read "silica", and on page 68 "eleactric" should read "electric."

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